GOVT. POLYTECHNIC SAMBALPUR, RENGALI

Renewable Energy Sources

LECTURE NOTES

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DEPARTMENT OF ELECTRONIC AND TELECOMMUNICATION ENGINEERING

Year & Semester: 3RD Year, VI Semester E&TC ENGINEERING

Subject Code/Name: TH-4, RENEWABLE ENERGY SOURCES

Th.4(i)- RENEWABLE ENERGY SOURCES
(Elective)

Name of the Course: Diploma in **Electronics & Communication** Engineering			
Course code:		Semester	6^{th}
Total Period:	60	Examination	3 hrs
Theory periods:	4P / week	Class Test:	20
Tutorial:		End Semester Examination:	80
Maximum marks:	100		

A. RATIONALE:

Renewable energy technologies enable us to create electricity, heat and fuel fromrenewable sources. Solar, wind, hydro, wave, heat-exchange, tidal, wave and bioenergy technologies are all powered by the sun, directly or indirectly. The movement of wind and water, the heat and light of the sun, the carbohydrates in plants, and the warmth in the Earth—all are energy sources that can supply our needs in a sustainable way. A variety of methods are used to convert these renewable resources into electricity. Each comes with its own unique set of technologies, benefits, and challenges. Solar energy—power from the sun—is a vast and inexhaustible resource that can supply a significant portion of our electricity needs. A range of technologies is used to convert the sun's energy into electricity, including solar collectors and photovoltaic panels.

B. OBJECTIVE:

After completion of this subject the student will be able to know:

1. Know abut Energy Situation and Renewable Energy Sources
2. DefineRenewable and Non-renewable Energy Sources
3. Know about Solar Radiation & Collectors
4. Explain Flat Plate Collectors
5. What are the Applications of Solar Energy.
6. Explain Solar Drying & Solar Pond
7. Know Passive Space Conditioning & Collectors
8. Know Energy losses
9. Define Solar Thermal Power Plants
10. Define Solar Photovoltaics
11. Explain Wind Energy & Wind Direction ,Measurements & Wind Direction Indicators
12. Explain Wind Energy Converters & Components of a Wind Power Plant
13. Explain Biomass system

C. Topic wise distribution of periods:

Sl. No.	Topics	Period
1	Energy Situation and Renewable Energy Sources	05
2	Solar Radiation & Collectors	06
3	Low-Temperature Applications of Solar Energy.	06
4	Passive Space Conditioning & Collectors	07
5	Solar Thermal Power Plants	08
6	Solar Photovoltaics	08
7	Wind Energy	05
8	Wind Energy Converters	08
9	Energy economics	07
	Total:	**60**

D. COURSE CONTENTS:

1. Energy Situation and Renewable Energy Sources

1.1 Renewable and Non-renewable Energy Sources

1.2 Energy and Environment

1.5 Direct-use Technology

2. Solar Radiation & Collectors

2.1 Solar Radiation Through Atmosphere
2.2 Terrestrial Solar Radiation
2.3 Measurement of Solar Radiation
2.4 Classification of Solar Radiation Instruments
2.5 Flat Plate Collectors
2.6 Optical Characteristics

3. Low-Temperature Applications of Solar Energy.

3.1 Swimming Pool Heating
3.2 Solar water Heating Systems
3.3 Natural Convection water Heating Systems
3.4 Solar Drying
3.5 Solar Pond

4. Passive Space Conditioning & Collectors

4.1 Principle Space conditioning
4.2 Passive building concepts- Heating, Direct gain, Indirect Gain, Passive Cooling, Shading,Paints, Collings
4.3 Construction of Concentrator
4.4 Energy losses

5. Solar Thermal Power Plants

5.1 Introduction
5.2 Solar Collection System
5.3 Thermal Storage for Solar Power Plants
5.4 Capacity Factor and Solar Multiple
5.5 Energy Conversion

6. Solar Photovoltaics

6.1 Band Theory of Solids, Physical Processes in a Solar Cell ,
6.2 Solar Cell Characteristics
6.3 Equivalent Circuit Diagram of Solar Cells
6.4 Cell Types - Crystalline Silicon Solar Cell , Solar Cells for Concentrating Photovoltaic Systems , Dye –sensitized Solar Cell (DSC)
6.5 Solar Module
6.6 Further System Components -Solar inverters ,Mounting Systems,Storage Batteries ,Other System Components
6.7 Grid-independent Systems -System Configuration
6.8 Grid-connected Systems -Small Roof Top Systems ,Medium-scale PV Generator ,Centralized System

7. Wind Energy

7.1 Wind Flow and Wind Direction
7.2 Wind Measurements
7.3 Measurement of Pressure Head
7.4 Hot wire Anemometer
7.5 Cup Anemometer (Robinson's Anemometer)
7.6 Wind Direction Indicators

8. Wind Energy Converters

8.1 Historical Development
8.2 Aerodynamic of Rotor Blade -Wind Stream Profile -Buoyancy Coefficient and the Drag Coefficient
8.3 Components of a Wind Power Plant -Wind Turbine -Tower -Electric Generators – Foundation
8.4 Power Control -Slow Rotors; Poor Control Mechanism -Control of Fast Rotors

9. Energy economics:

9.1 Present worth, Life cycle costing (LCC), Annual Life cycle costing(ALCC), Annual savings. calculations for Solar thermal system
9.2 Solar PV system,
9.3 Wind system,

9.4 Biomass system

Syllabus coverage up to Internal assessment

Chapters: 1, 2, 3 and 4.

Learning Resources:

Non-Conventional Energy Sources and Utilisation by R.K. Rajput, , S. Chand
Solar energy: Principles of Thermal Storage by S P Sukhatme, , Tata Mc Graw Hill
Non Conventional Energy Sources by N. K. Bansal
Non Conventional Energy Sources by B. H. Khan Tata Mc Graw Hill
Solar energy Utilization ByG.D.Rai: Khanna Publisher

ENERGY SITUATION AND RENEWABLE ENERGY SOURCES

(1.1) RENEWABLE AND NON-RENEWABLE ENERGY SOURCES

RENEWABLE ENERGY SOURCES

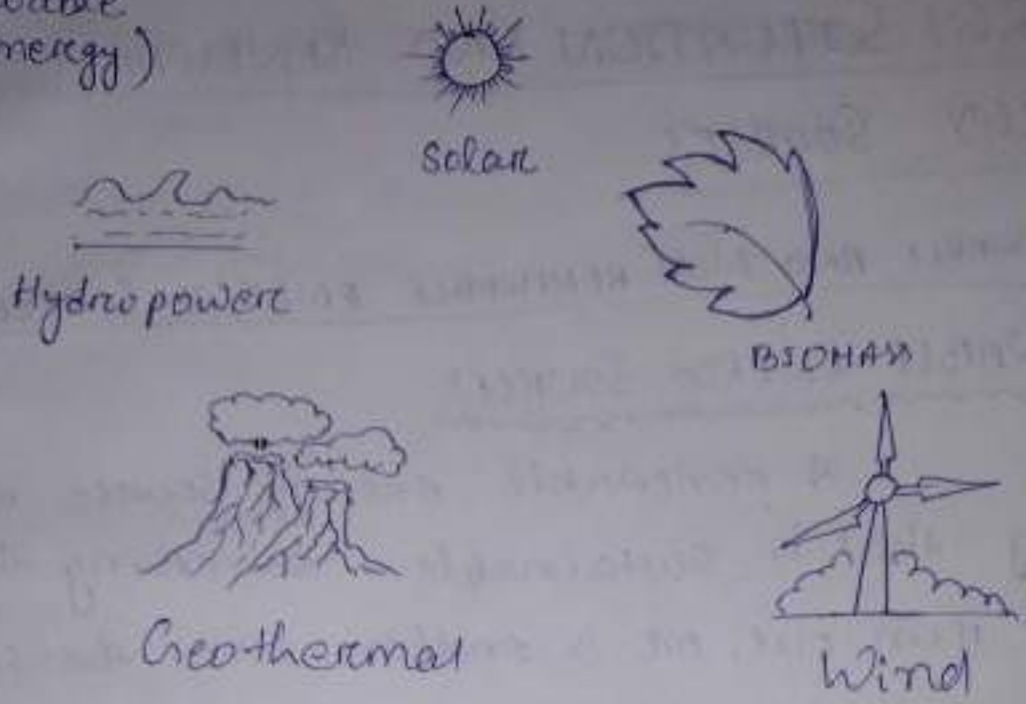
A renewable energy source means energy that is sustainable - something that can't run out, or is endless, like the sun.

-> When we hear the term 'alternative energy' it's usually reffering to renewable energy sources too. It means source of energy that are alternative to the most commonly used non-sustainable sources like coal.

The most popular renewable energy sources currently are.

1. Solar energy
2. Wind energy
3. Hydro energy
4. Tidal energy
5. Geothermal energy
6. Biomass energy

(Renewable energy)



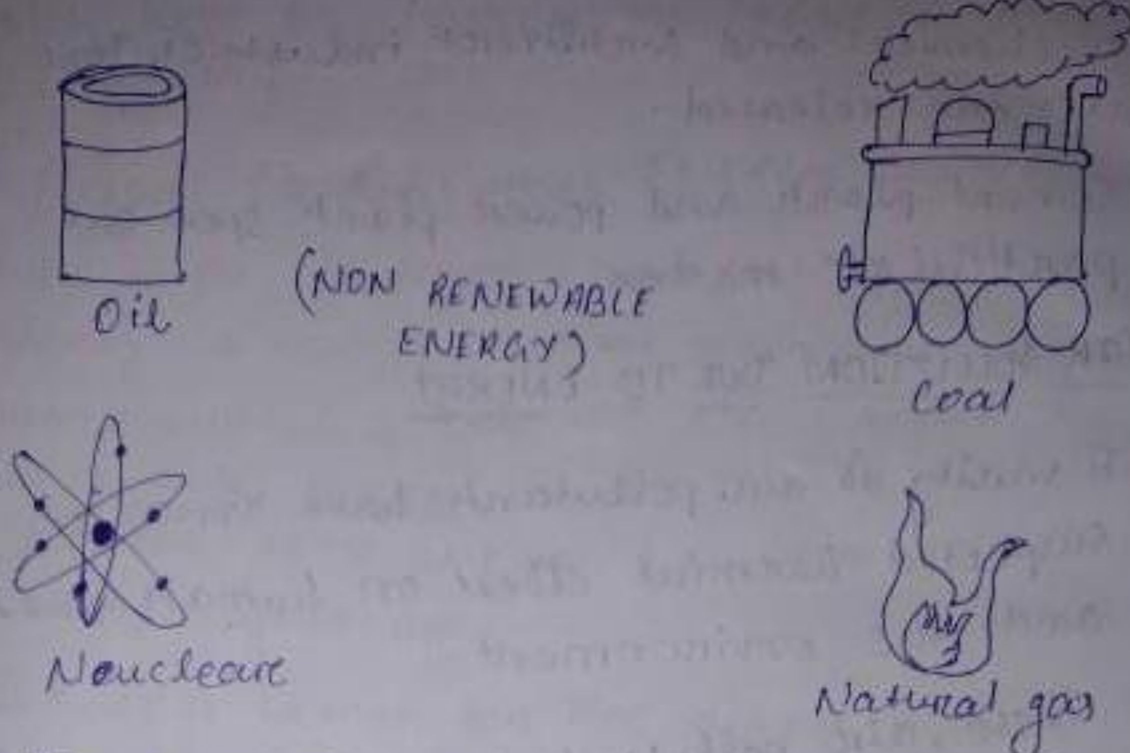
NON-RENEWABLE RESOURCE

Non - renewable resources are those that are available to us in limited quantities, or those that are renewed so slowly that the rate at which they are consumed is too fast.

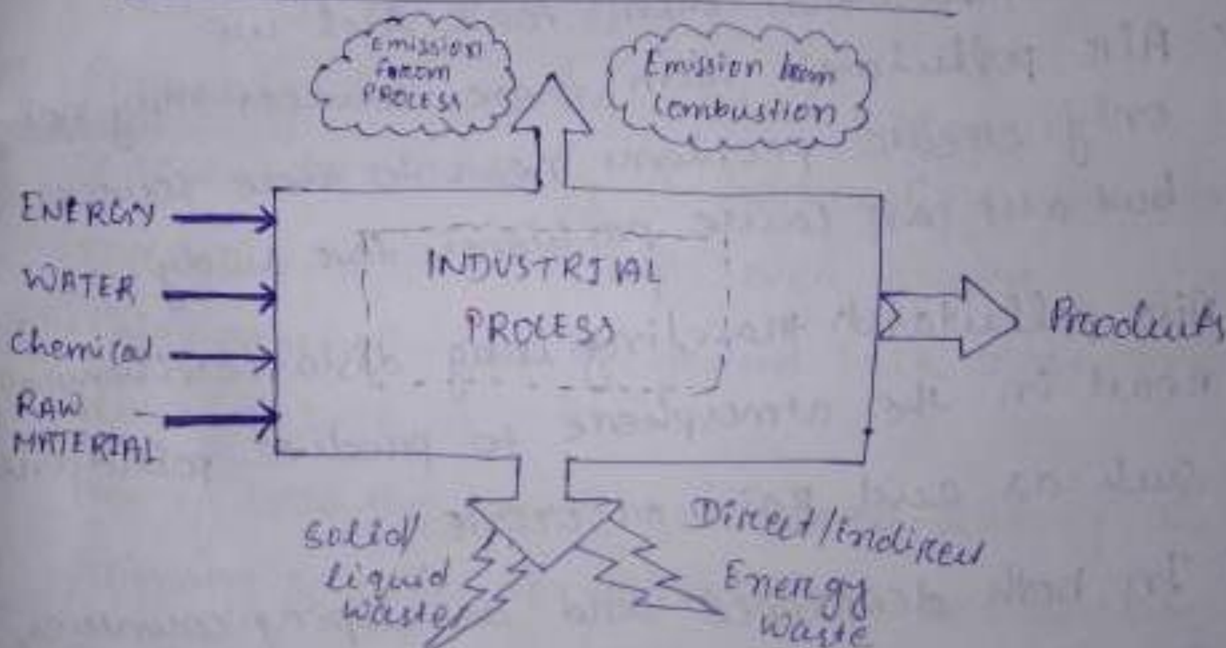
-> This means their stocks are getting depleted before they can replenish naturally.

-> Some of the best example of non-renewable resources are

i) Coal
ii) Uranium
iii) gold
iv) aluminium
v) Sand
vi) Natural oil
vii) Petroleum



(1.2) ENERGY AND ENVIRONMENT



→ The use of energy resources in industry leads to environmental damage by polluting the atmosphere.

→ Few of examples of air pollution are sulpher dioxide (SO_2), nitrous oxide (NO_x) and carbon monoxide (CO) emissions from boiler and furnaces, chloroflurow carbons (CFC) emission from refrigirants we etc.

→ In chemical and fertilizers industries, toxic gases are released.

→ Cement plants and power plants spew out particulate matter.

- AIR POLLUTION DUE TO ENERGY.

→ A varity of air pollutants have known or suspected harmful effect on human health and the environment.

→ These air pollutants are basically product of combu-stition from fossil fuel use.

→ Air pollutants from these sources may not only create problems near to these sources but also can cause problems far away.

→ Air pollutants traveling long distances, chemically react in the atmosphere to produce pollutants such as acid rain or ozone.

→ In both developed and developing countries, the major threat to clean air is now posed by traffic emissions.

→ Petrol and diesel engine motor vehicles emit a wide varity of pollutants, principally carbon monoxide (CO), oxide of nitrogen (NO_x), voltile organic compounds (VOCs) and particulates, which have an increasing impact on urban air quality.

(1.3) ORIGIN OF RENEWABLE ENERGY SOURCES

Prior to the development of coal in 19th century, nearly all energy used was renewable.

→ Almost without a doubt the oldest known of renewable energy, in the form of traditional biomass to fuel fires, dates from more than a million year ago.

→ The use of biomass for fire did not become common-place until many hundreds of thousands of years later.

→ Probably the second oldest usage of renewable energy is harnessing the wind inorder to drive ships over water.

→ This practice can be traced back some 7000 years before

→ Moving into the time of recorded history, the primary sources of traditional renewable energy were human labour, animal power, water power, wind, in grain crushing windmills, and firewood, a traditional biomass.

→ Renewable energy sources can be used to produce electricity with fewer environmental impacts.

→ It is possible to make electricity from renewable energy sources without producing CO_2, the leading

Cause of global climate change

→ Renewable energy is energy derived from natural resources that replenish themselves over a period of time without depleting the earth's resources.

→ These resources also have benefit of being abundant, available in same capacity nearly everywhere and cause ~~very little~~ rarely environmental damage.

→ Energy from sun, wind and thermal energy stored in the earth's crust are examples.

→ For comparison, fossil fuels such as oil, coal, natural gas are not renewable since their quantity is finite.

→ Once we have extracted them they will cease to be available for use as an economically viable energy source.

→ While they are produced through natural process these processes are ~~that~~ too slow to replenish these fuels as quickly as humans use them, so these sources will run out sooner or later.

→ Renewable energy provides many benefits to people, business and the planet.

(1·4) POTENTIAL OF RENEWABLE ENERGY SOURCES

In spite of some little disadvantages, there are a number of applications where renewable energy system can be employed efficiently and economically.

GEOTHERMAL ENERGY

→ The word Geothermal comes from word geo (earth) and thermal (heat)

→ Therefore geothermal energy is the heat from earth.

→ Core of earth continuously produces temperature higher than the sun's surface by slow decay of radio active particles.

→ The earth has a number of different layers.

→ The temperature get raised when we going deep in the earth surface.

→ Due to the temperature difference between the earth's core and the upper surface of the earth, there is a constant heat flow on the earth's surface with an average value of $63 kW/km^2$. If we consider this heat flow as an available energy source, the world's annual available energy could be around 3×10^{20} J.

→ There are various way of utilizing geothermal energy sources, like

1) Dry steam Sources

It may be used to run a turbine and subsequent production of electricity.

2) Wet steam Sources

Same as dry steam sources.

3) Hot water resources

In here allow the steam of water flow through hot rocks and get that stream of water and steam and then we use that hot water and steam as live dry steam sources or wet steam source.

POWER GENERATION TECHNOLOGY

1) Direct steam geo thermal plant :-

→ Here we can use direct coming stream from the earth well to feed the turbine.

→ A separator is used to remove small sand and rock particles before steam is allowed to the enter the turbine.

2) Flash steam Power plan

→ This type of plant is used when resources produce high temp. hot water or a mixture of steam and hot water.

→ Fluid from the well is directed to a flash tank, where sore quantity of hot water is converted into steam. This steam is directed to the turbine.

→ After work is done, the steam condences in the condencer which is brought to the cooling floor.

3) <u>Binary Cycle Power Plant</u>

→ The name 'binary' for this technology comes from the fact that a second fluid (in place of geothermal steam) is used to operate the turbine.

(1.5) DIRECT USE TECHNOLOGY

Solar Energy

Solar energy comes from the sun. and is harvested with several technologies, including solar panels.

WIND POWER

Wind turbines capture the wind's power as they spin and convert it to electricity.

Hydroelectricity

Hydropower turbines rotate as water flows through them, generating electricity.

Geothermal Energy

Heat enearegy from within the earth can be harnessed to generate power.

Biomass

Biomass fules are recently living organic matter (like plants and animals) that are burned for power.

CHAPTER-2

SOLAR RADIATION AND COLLECTORS

(2.1) SOLAR RADIATION THROUGH ATMOSPHERE

→ Solar radiation often called the solar resources or just sunlight, is a general term for electromagnetic radiation emitted by the sun.

→ Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using variety of technologies.

→ However, the technical feasibility and economical operation of these technologies at a specific location depends on the available solar resource.

BASIC PRINCIPLES

Every location on earth receives sunlight at least part of the year. The amount of solar radiation that reaches any one spot on the Earth's surface varies according to

- Geographic location
- Time of day
- Season
- Local landscape

• Local Weather

Because the Earth is round, the sun strikes the surface at different angles, ranging from 0° (just above the horizon) to 90° (directly overhead).

→ When the sun's rays are vertical, the Earth's surface gets all the energy possible.

→ The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse.

→ Because the Earth is round, the frigid polar regions never get a high sun, and because of the tilted axis of rotation, these areas receives no sun at all during part of the year

→ The earth revolves around the sun in an elliptical orbit and is closer to the sun during part of the year.

→ When the sun is nearer the earth, the earth's surface receives a little more solar energy.

→ The earth is nearer the sun when it is summer in the southern hemisphere.

→ However, the presence of vast oceans moderates the hotter summers and colder winters one would expect to see in the southern hemisphere as a result of this difference.

→ This is called diffused solar radiation.

→ The solar radiation that reaches the earth's surface without being diffused is called direct beam solar radiation.

→ The sum of the diffuse and direct solar radiation is called global solar radiation.

→ Atmospheric conditions can reduce direct beam radiation by 10% on clear, dry days and 100% during thick, cloudy days.

MEASUREMENT

Scientists measure the amount of sunlight falling on specific locations at different times of the year.

→ They then estimate the amount of sunlight falling on the region

(2.2) TERRESTRIAL SOLAR RADIATION

While the solar radiation incident on the Earth atmosphere is relatively constant, the radiation at the Earth's surface varies widely due to:

* atmospheric effects, including absorption and scattering;
* local variations in the atmosphere, such as water vapour, clouds and pollution;
* latitude of the location; and

* the season of the year and the time of day.

The above effects have several impacts on the solar radiation received at the Earth's surface.

→ These changes include variations in the overall power received, the spectral content of the light and the angle from which light is incident on a surface in addition a key change is that the variability of the solar radiation at a particular location increases dramatically.

→ The variability is due to both local effects such as the length of the day at a particular latitude.

→ Desert regions tend to have lower variations due to local atmospheric phenomena such as clouds.

→ Equatorial regions have low variability between seasons.

→ Solar radiation at the Earth's surface varies from the solar radiation incident on the Earth's atmosphere.

→ Cloud cover, air pollution, latitude of a location, and the time of the year can all cause variations in solar radiance at the

Earth's surface.

→ The amount of energy reaching the surface of earth every hour is greater than the amount of energy used by the Earth's population over an entire year.

(2.3) MEASUREMENT OF SOLAR RADIATION

Scientists measure the amount of sunlight falling on specific locations at different times of the year.

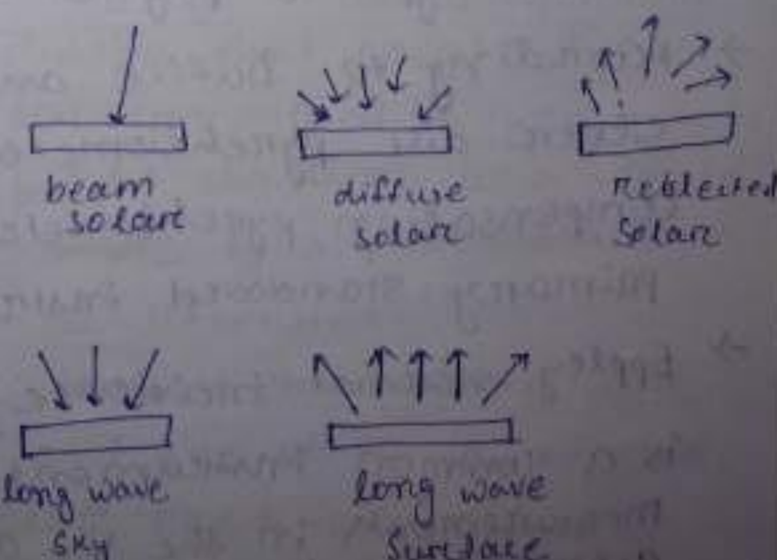
→ They then estimate the amount of sunlight falling on regions at the same latitude with similar climates.

→ Measurements of solar energy are typically expressed as total radiation on a surface tracking the sun.

DIFFUSE AND DIRECT SOLAR RADIATION

As sunlight passes through the atmosphere, some of it is absorbed, scattered and reflected by:

→ Air molecules
→ Water vapor
→ Clouds
→ Dust
→ Pollutants
→ Forest fires
→ Volcanoes



This is called diffuse solar radiation.

→ The solar radiation that reaches the Earth's surface without being diffused is called direct beam solar radiation.

→ The sum of the diffuse and direct solar radiation is called global solar radiation.

(2.4) CLASSIFICATION OF SOLAR RADIATION INSTRUMENTS

The amount of solar radiation on the earth surface can be instrumentally measured, an precise measurements are important for providing background solar data for solar energy conversion applications

There are two important types of instruments to measure solar radiation:

1. Pyrheliometer

Pyrheliometer is used to measure direct beam radiation at normal incidence. There are different types of pyrheliometer.

→ According to Duffie and Beckman (2013), Abbo silver disc pyrehliometer and Angstrom compensation pyrehliometer and important primary standard instruments.

→ Eppley normal incidence pyrheliometer (NIP) is a common instrument used for practical measurements in the US, and Kipp and Zonen actinometer is widely used in Europe

→ Both of these instruments are calibrated against the primary standard methods.

→ Based on their design, the above listed instruments measure the beam radiation comming from the sun and a small portion of sky around the sun.

2. PYRANOMETER

It is used to measure total hemispherical radiation - beam plus diffuse - on horizontal surface.

→ If shaded, a pyranometer measures diffuse radiation.

→ Most of solar resources data come from pyranometers.

→ The total irradiance (W/m²) measured on a horizontal surface by a pyranometer is expressed as follows.

3. PHOTOELECTRIC SUNSHINE RECORDER

The natural solar radiation is notoriously intermittent and varying intensity.

→ The most potent radiation that creates the highest potential for concentration and conversion is the bright sunshine at a locale. is measured, for example by a ~~photovoltaic~~ photoelectric sunshine recorder.

→ The device has two selenium photovoltaic cells, one of which shaded and the other is exposed to the available solar radiation.

→ When there is no beam radiation, the signal output from both cells is similar, while in bright sunshine, signal difference between the two cells is maximized.

→ This technique can be used to monitor the bright sunshine hours.

(2.5) FLAT PLATE COLLECTORS

→ Flat plate collector absorbs both beam and diffuse components of radiant energy.

→ The absorber plate is a specially treated blackened metal surface.

→ Sun rays striking the absorber plate are absorbed causing rise of temperature of transport fluid.

→ Thermal insulation behind the absorber plate and ~~transport~~ transparent cover sheets (glass or plastic) prevent loss of heat to surroundings.

Applications of flat plate Collectors

1. Solar water heating systems for residence, hotels, industry.
2. Desalination plant for obtaining drinking water from sea water.
3. Solar cookers for domestic cooking.
4. Drying applications.

5. Residence heating.

Losses in flat plate collector.

1. **Shadow effect:** Shadows of some of the neighbor panel fall on the surface of the collector. Where the angle of elevation of the sun is less than 15° (sun-rise and sunset).

$$\text{Shadow factor} = \frac{\text{Surface of the collector receiving light}}{\text{Total surface of the collector}}$$

Shadow factor is less than 0.1 during morning and evening. The effective hours of solar collectors are between 9AM and 5PM.

2. **Cosine loss factor:** For maximum power collection, the surface of collector should receive the sun rays perpendicularly. If the angle between the perpendicular to the collector surface and the direction of sun rays is θ, then the area of solar beam intercepted by the collector surface is proportional to cosθ.

3. **Reflective loss factor.**

The collector glass surface and the reflector surface collect dust, dirt, moisture etc. The reflector surface gets rusted, deformed and loses the shine. Hence, the efficiency of the collector is reduced significantly with passage of time.

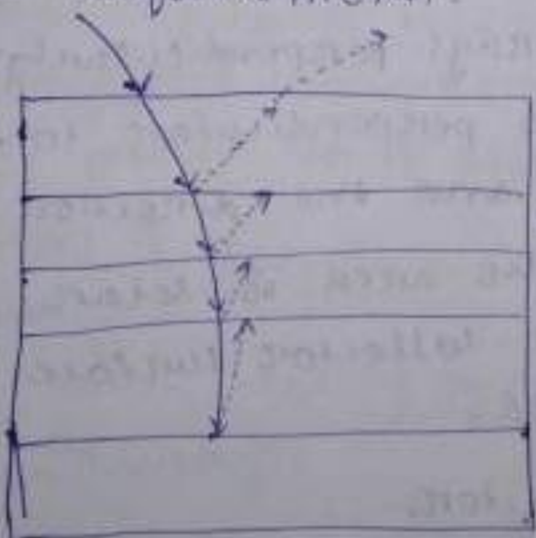
Maintenance of flat plate collector

1. Daily cleaning
2. Seasonal maintenance (cleaning, touch-up paint)
3. Yearly overhaul (change of seals, cleaning after dismantling)

(2.6) OPTICAL CHARACTERISTICS

In this section we will deal with the optical aspects of the materials used in solar cells.

→ Generally, solar cells are built from different elements, and beside their electric importance most of them also have to fulfill important optical requirements.



The figure shows a typical stack of the active layers in solar cell.

→ The incident light first strikes the

encapsulation, usually consisting of a glass plate and some organic glue.

-> The first active functional layer of a solar cell is the antireflection coating. It's job is the minimisation of reflection losses by means of optical interference.

-> The next element is the front contact. This layer must combine high optical transparency with high electric conductivity, two properties which normally exclude eachother.

-> Electric conduction is usually observed in metals but they are not transparent.

-> However, highly doped semiconductors are transparent for light with energy less than the bandgap and they can transport certain amounts of current.

-> For transmission of visible light we need either bandgaps of more than 3 eV or low absorption coefficients like those of indirect semiconductors, eg silicon.

-> For heterojunction devices oxides like ZnO and SnO_2 are used due to their high bandgaps and easy dopability.

-> The next layer on the way into the solar cell is the n-layer, a vital part of pn-junction. Usually it is intended to avoid absorption in the n-layer, thus, also this layer should consist of a wide bandgap semiconductor or one with low absorption.

-> Finally, if light has not been absorbed and reaches the back contact, it should be reflected back into the absorber.

-> Thus the back contact must be a good electric contact and a good optical reflector.

-> Recently, in thin film solar cells transperent back contacts have attracted much attention, they allow for bifacial illumunation or the application of separate, highly reflecting mirrors.

chapter-3

LOW TEMPERATURE APPLICATIONS OF SOLAR ENERGY

(3.1) SWIMMING POOL HEATING SYSTEM

→ Heating your outdoor swimming pool with a swimming pool heating system powered by the sun is a simple and effective way to both lower your energy bills and keep your outdoor pool warm enough to swim throughout the year all at the same time.

→ Solar swimming pool heating systems are easy to install and will last for years providing you with plenty of free solar hot water.

→ Just like the home solar heating systems, they can turn the immense heat energy from the sun into something useful.

→ A solar pool heating system is a very simple heating system to install and operate, all you need is a solar panel, a few pipes and may be a pump.

→ A typical solar pool heating system can provide sufficient hot water for an outdoor garden pool or even a jacuzzi of any shape or size as long as you have enough flat panel solar collectors in your system

So HOW DOES SWIMMING POOL HEATING WORK

-> A solar powered swimming pool heating system does not have to be complicated

-> A typical system consists of a flat panel solar collector, a filter, a pump and some tubing.

-> The swimming pool water is circulated through a flat panel solar collector, usually mounted on a garage or outbuilding roof or next to the pool itself.

-> The solar panel or panels can be glazed or unglazed the choice is yours however, there is a big difference in cost.

-> The water is heated by the suns solar energy which is absorbed by the water flowing over or through the panel before the heated water is returned back to the pool.

-> An optional filter can be used to remove the dirt, leaves and debries before the water is pumped through the solar collector and back to the pool using suitable plastic or copper tubing.

-> Swimming pool heating sytems do not require a separate water storage tank, since the pool itself serves as the storage tank and in most cases, the pools filtration pump can be used to circulate the swimming pool water through the filter and solar collector making it an active system with force circulation of the heated water.

-> In hot climates or the middle of summer, the solar collector can also be utilized to cool the pool, by circulating the water around the system at night with the solar panel acting as a radiator instead of a solar collector.

-> If you want to heat your pool during the colder winter months and weathers, a more advanced closed loop system may be required which; includes anti freeze and frost-protection

-> There are many different solar pool collectors available in the marketplace. Each with their individual advantages and disadvantages.

-> The size of the solar collector required for solar pool heating is determined by many factors, including:

-> geographic location

-> Size and shape of your pool

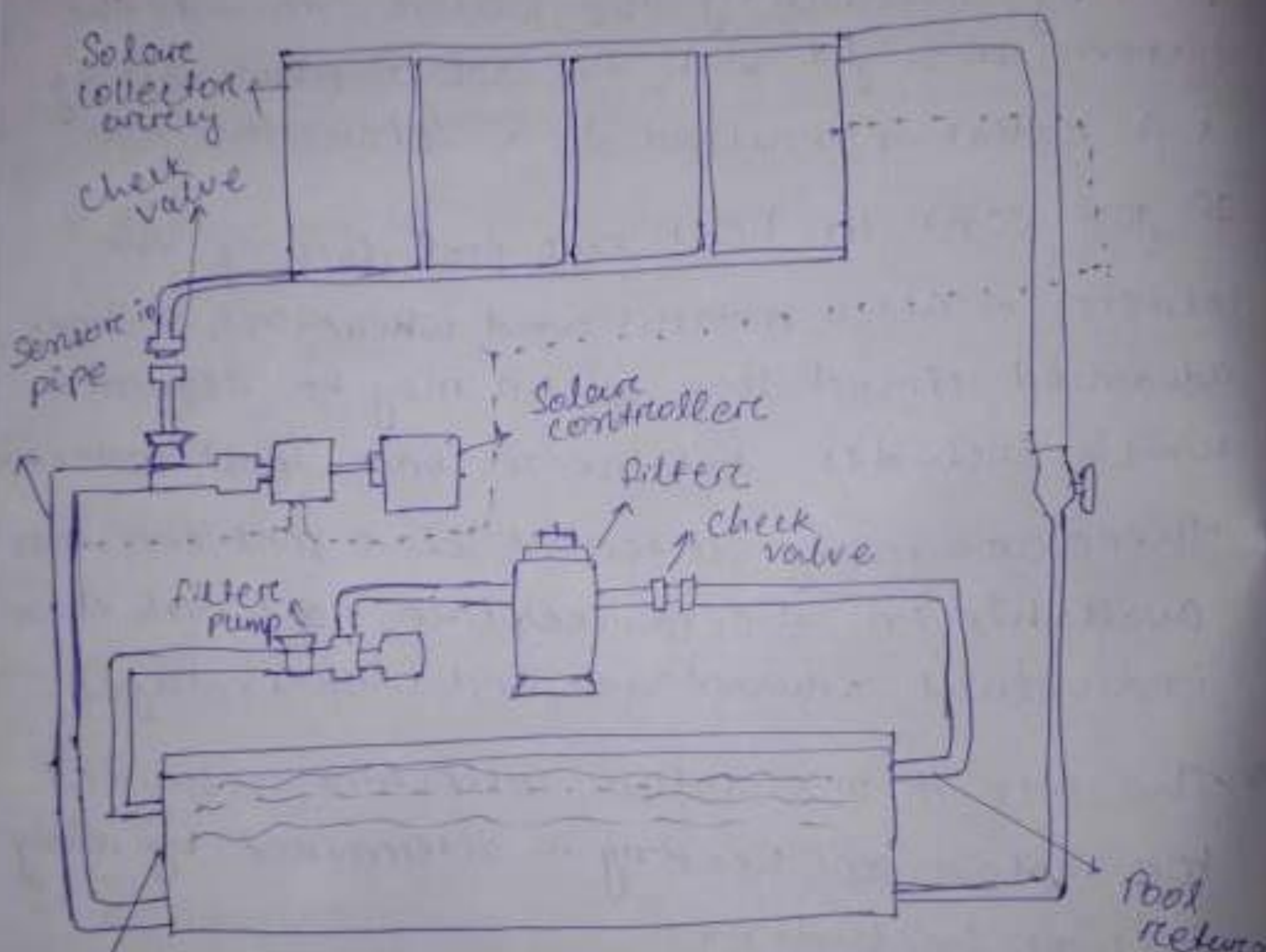
-> desired pool temperature

-> Swimming season

-> and length of time required to reheat the pool as well as wind conditions and shading from trees, walls or fences, etc.

-> But a general rule of thumb is that you will need a system that is equal to about 50 to 80% of the pool surface area.

→ That is the surface area of the water and not the volume of water.



(Swimming heating System)

(32) # SOLAR WATER HEATING SYSTEM

INTRODUCTION TO SOLAR WATER HEATERS

Solar water heating system is a device that uses solar energy to heat water for domestic, commercial, and industrial needs.

→ Heating of water is the most common application of solar energy in the world.

→ A typical solar water heating system can ~~gave~~ save upto 1500 units of electricity every year, for every 100 litres per day of solar water heating capacity.

PARTS OF THE SOLAR WATER HEATING SYSTEM

A solar water heating system consists of a flat plate solar collector; a storage tank kept at a height behind the collector, and connecting pipes.

→ The collector usually comprises copper tubes welded to copper sheets (both coated with a highly absorbing black coating) with a toughened glass sheet on top and insulating material at the back. The entire assembly is placed in a flat box.

→ In certain models, evaluated glass tubes are used instead of copper; a separate cover sheet and insulating box are not required in this case.

WORKING OF A SOLAR HEATER

The system is generally installed on the roof or open ground, with the collector facing the sun and connected to a continuous water supply.

-> Water flows through the tubes, absorbs solar heat and becomes hot.

WORKING OF A SOLAR WATER HEATER

The system is generally installed on the roof or open ground, with the collector facing the sun and connected to a continuous water supply.

-> Water flows through the tubes, absorbs solar heat and becomes hot

-> The heated water is stored in a tank for further use

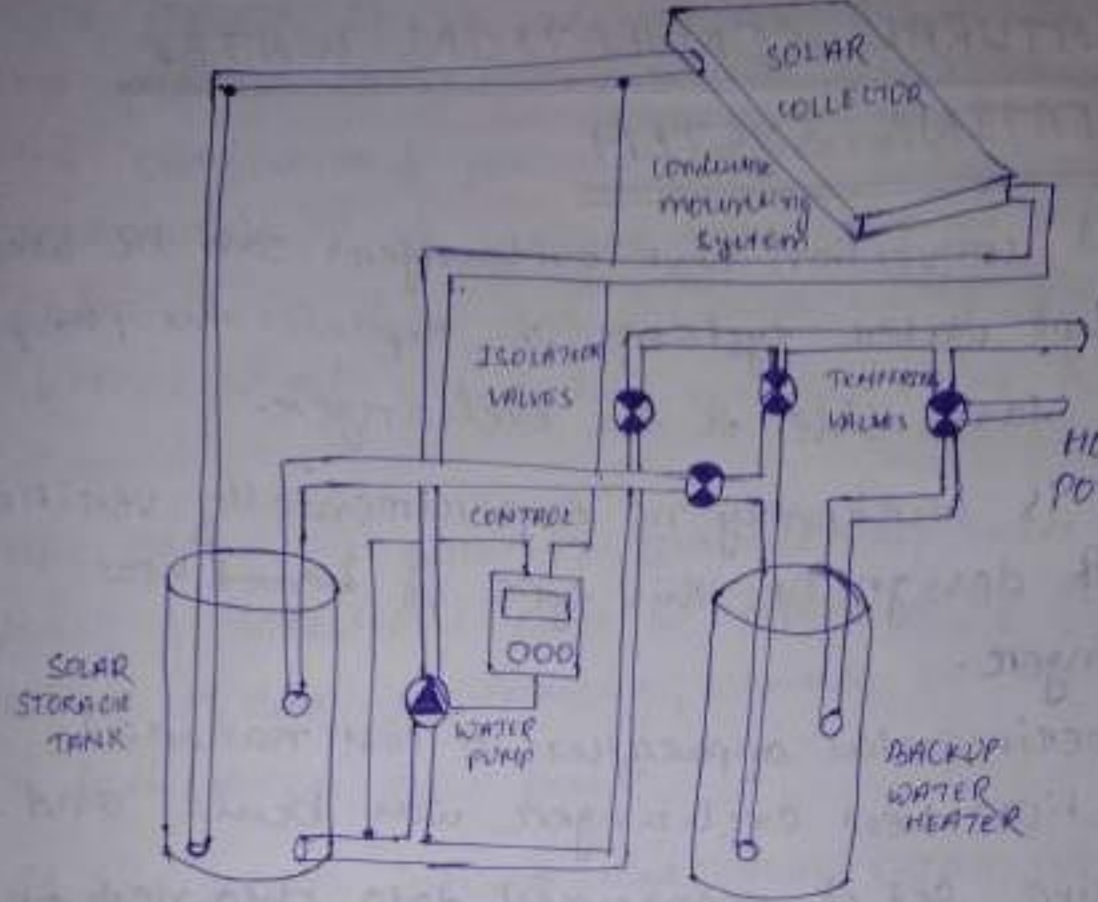
-> The water stored in the tank remains hot overnight as the storage tank is insulated and heat losses are small

HOW DO SOLAR WATER HEATERS WORK

The working of solar water heaters is very simple to understand.

-> The solar water heaters use two common principles for it's functioning. They are

-> A black surface heats up when left in the sun, by absorption of solar radiation; The good absorb...



(SOLAR WATER HEATING SYSTEM)

in a solar heater.

-> The inside of car/bus parked in sun for a long time becomes hot. This is because solar radiation can pass through the glass windows of the bus but cannot come out.

-> It is trapped inside and thus heats up the bus. Similarly water passing through ~~insult~~ insulated pipes kept in the sun becomes hot.

These two phenomena are utilized in flat plate collectors & commonly available solar water heaters.

(3.3) NATURAL CONVECTION WATER HEATING SYSTEM

Natural convection heat exchangers can be used in solar hot water systems to replace the pump on the tank side of the exchanger.

→ There is currently no experimentally verified way of designing this type of ~~heart~~ heat exchanger.

→ An experimental apparatus to test natural convection heat exchanger was built, and an extensive set of measured data obtained on two different exchangers sized for low-flow stratified tank system.

→ Two theoretical models for the exchanger are presented: a finite-volume primitive variable numerical solution of the fundamental laminar equations of fluid motion and a laminar forced convection-based solution method.

→ Comparison of the model predictions with the experimental data showed good agreement when the modified Rayleigh number is less than about 400.

→ The poor agreement under other conditions was attributed to turbulence and recirculation neither of which was accounted for in the models.

→ The separation of sodium nitrate from 'caliche' and potassium chloride from "silvinita", and the obtention of potassium nitrate from double decomposition of sodium nitrate and potassium chloride in aqueous solution, using the differential solubility method, hew, has been treated.

→ The necessary energy for solving salts and heating solutions can be provided by the sun if solar ponds - of caliche, silvinita or a mixture of both ores - are built.

→ It has been found that this solar pond application is feasible, and the cycling pond efficiency could be improved beyond the typical 20% at low operating temperature.

→ The amount of nitrate or chloride obtained per liter of solution depends on the temperature at the bottom of the pond, the ambient temperature and, especially, on their difference.

→ Finally, pond stability is improved to the higher stability is improved to the higher solubility of the salts used, and the pond of "silvinita" could be stable even if evolving to a saturation operational pond.

(3.4) # SOLAR DRYING

WHAT IS SOLAR DRYER?

Solar dryers are devices that use solar energy to dry substances, especially food. There are two general types of solar dryers: Direct and indirect.

DIRECT

Direct solar dryers expose the substance to be dehydrated to direct sunlight. They have a black observing surface which collects the light and converts it to heat; the substance to be ~~direct~~ dried is placed directly on this surface. These driers may have enclosures, glass covers and/or vents to in order to increase efficiency.

INDIRECT

In Indirect solar dryers, the black surface heats incoming air, rather than directly heating the substance to be dryied. This heated air is then passed over the substance and exists through a chimney, taking moisture from the substance with it.

PRINCIPLE OF SOLAR DRYER

→ Solar dryer is based on two principles

CONVECTION OF ENERGY

Convection of energy in which one form of energy is converted into other form of energy.

BLACK BODY

Black body which absorbs the heat of the incident sunlight and makes the temperature of chamber more than the surrounding temperature.

CONSTRUCTION OF SOLAR DRYER

1) Solar panel: 12 volt and 10 watt
2) Electric motor: 150 rpm
3) Black absorbing wooden chamber.
4) Glass cover: traps the heat generated and act as insulator.
5) Electric bulb: (denoting sun): 200 watt
6) Plastic container: To collect sand, pebbles, impurities.

SOLAR DRYING TECHNOLOGY

Advantages of Solar Drying System

→ Better quality of products are obtained.
→ It reduces Loses and better market price to the products.

→ Products are protectected against flies, rain and dust; product can be left in the dryer overnight during rain, since dryers are waterproof.

→ Prevent fuel dependance and reduces the environmental impact.

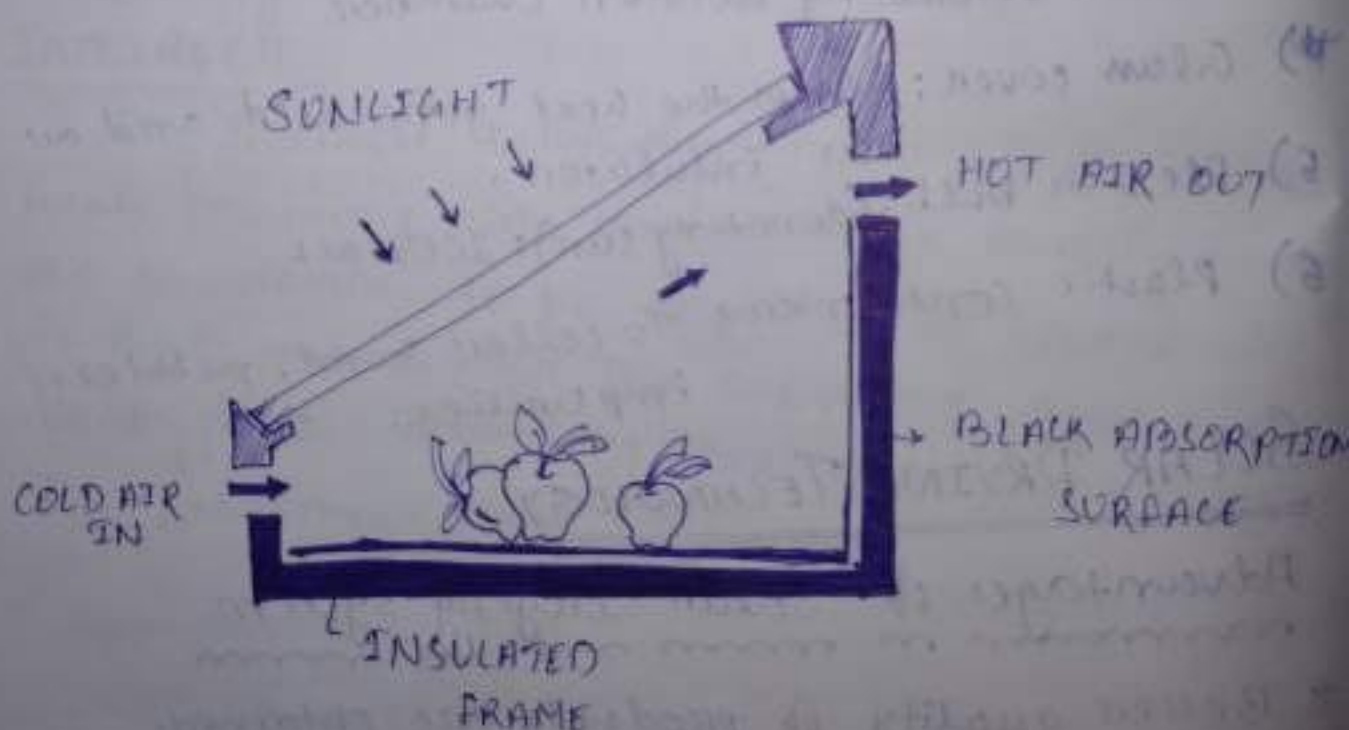
→ It is more efficient and cheap.

DISADVANTAGES OF SOLAR DRYING SYSTEM

→ Quality of products are not obtained in some cases.

→ Adequate solar radiation is quired.

→ It is more expensive as it requires more time for drying.



3.5 SOLAR POND

WHAT IS A SOLAR POND

→ A solar pond is a body of water that collects and stores solar energy. Solar energy will warm a body of water (that is exposed to sun), but the water loses its heat unless some method is used to trap it.

→ Water warmed by the sun expands and rises as it becomes less dense. Once it reaches the surface, the water loses its heat to the air through convection, or evaporates, taking heat with it.

→ The colder water, which is heavier, moves down to replace the warm water, creating a natural convective circulation that mixes the water and dissipates the heat.

→ The design of solar ponds reduces either convection or evaporation in order to ~~~~ store the heat collected by the pond.

→ They can operate in almost any climate.

→ A solar pond can store solar heat much more efficiently than a body of water of the same size because the salinity gradient prevents convection currents.

→ Solar radiation entering the pond penetrates through to the lower layer, which contains concentrated salt solution.

→ The temperature in this layer rises since the heat is absorbs from the sunlight is unable to move upwards to the surface by convection.
→ Solar heat is thus stored in the lower layer of the pond.

WORKING PRINCIPLE

→ The solar pond works on a very simple principle. It is well-known that water or air is heated they become lighter and rise upward.
→ Similarly, in an ordinary pond, the sun's rays heat the water and the heated water from within the pond rises and reaches the top but loses the heat into the atmosphere.
→ The net result is that the pond water remains at the atmospheric temperature. The solar pond restricts this tendency by dissolving salt in the bottom layer of the pond making it too heavy to rise.
→ The solar pond is an artificially constructed water and in which significant temperature rises are caused in the lower regions by preventing the occurrence of convection currents.
→ The more specific terms salt-gradient solar pond or non-convecting solar pond are also

used. The solar pond ~~[illegible]~~ which is actually a large area solar collector is a simple technology that uses a pond between one to four meters deep as a working material.

TYPES OF SOLAR PONDS

* CONVECTING SOLAR PONDS

→ A well ~~heath~~ researched example of a convecting pond is the shallow solar pond.

→ This pond consists of pure water enclosed in a large bag that allows convection but hinders evaporation.

→ The bag has a blackened bottom, has foam insulation below and two types of glazing on top.

→ The sun heats the water in the bag during the day.

→ At night the hot water is pumped into a large heat storage tank to minimize heat loss.

→ Excessive heat loss when pumping the hot water to the storage tank has limited ~~heat~~ the development of shallow solar ponds.

* NON CONVECTING SOLAR PONDS.

→ The main types of nonconvecting ponds is salt gradient ponds.

→ A salt gradient pond has three distinct layers of brine (a mixture of salt water) of varying concentrations.

→ Because the density of the brine increases with salt concentration, the most concentrated layer forms at the bottom.

→ The least concentrated layer is at the surface. The salts commonly used are sodium chloride and magnesium chloride.

→ A dark-colored material usually butyl rubber lines the pond.

→ As sunlight enters the pond, the water and the lining absorb the solar radiation.

→ As a result, the water ~~and the lining absorb the~~ solar near the bottom of the pond becomes warm upto 93.3°c. Even when it becomes warm, the bottom layer remains denser than the upper layers, thus inhibiting convection.

→ Pumping the brine through an external heat exchanger or an evaporator removes the heat from this bottom layer.

→ Another method of heat removal is to extract heat with a heat transfer fluid as it is pumped through a heat exchanger placed on the bottom of the pond.

ADVANTAGES

- Low investment cost per installed collection area.
- Thermal storage is incorporated into the collector and is of very low cost.
- Can operate in almost any climate.
- Can store solar heat much more efficiently than a body of water of same size.

APPLICATION

- Salt production
- Aquaculture, using saline or fresh water.
- Dairy industry (to preheat feed water to boilers)
- Fruits and vegetable canning industry
- Grain industry (for grain drying)
- Water supply (for desalination)

SOLAR POND CONSISTS OF THREE ZONES

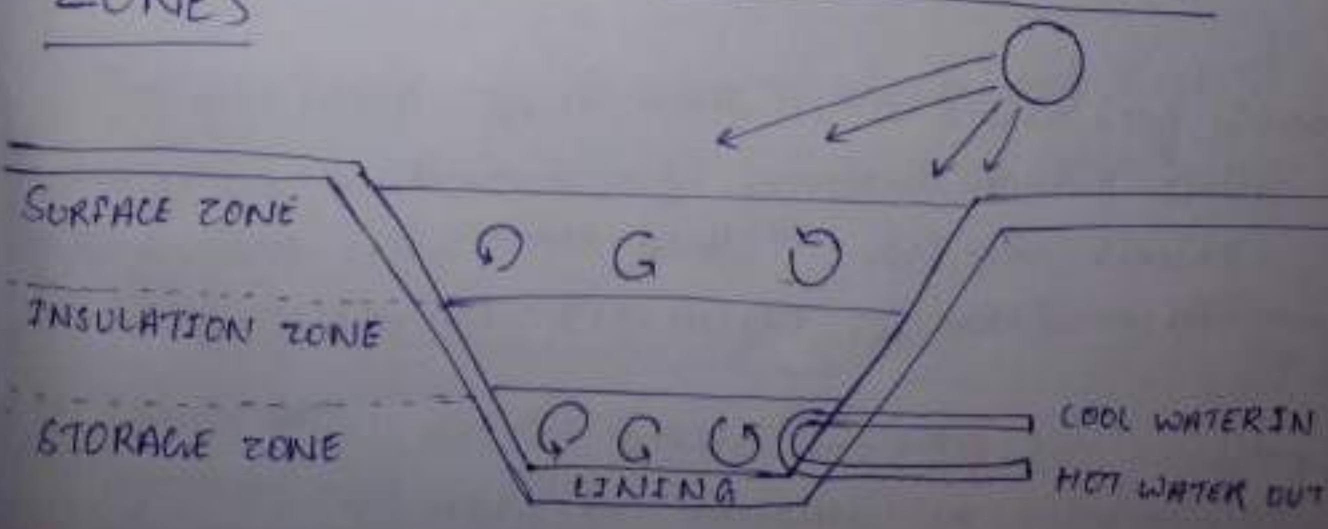


fig. Three zones of solar Pond

→ An upper convective zone of clear fresh water that acts as solar receiver.

→ A gradient which serves as the non-convective zone.

→ Lower convective zone with the densest salt concentration serving as the heat storage zone.

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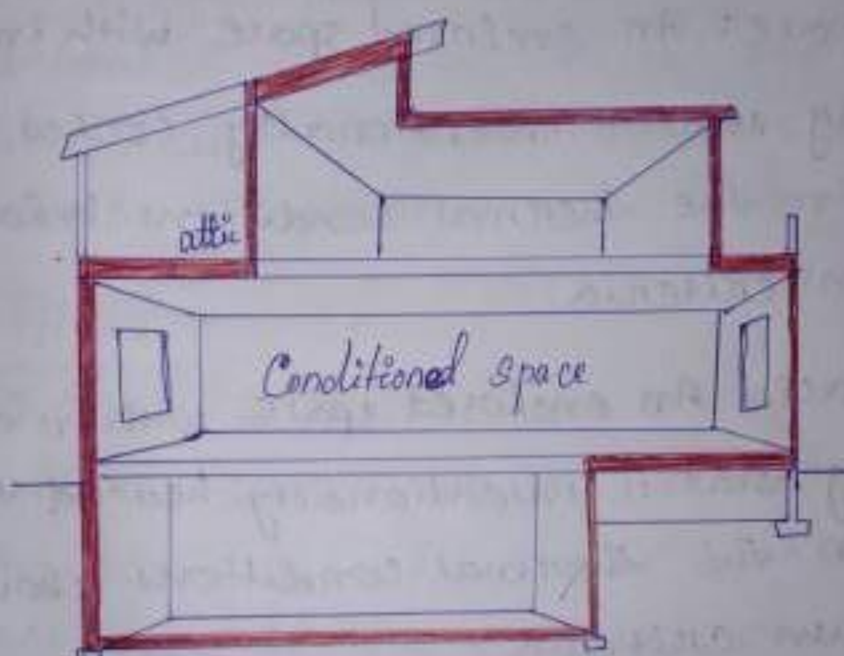
PASSIVE SPACE CONDITIONING AND COLLECTORS

4.1 PRINCIPLE OF SPACE CONDITIONING



An enclosed space with in a building where there is a intentional control of the space thermal conditions with in defined limits using natural, electrical, or mechanical means.

→ Spaces that do not have heating or cooling systems but rely on natural or mechanical flow of thermal energy conditions within defined limits are considered conditioned spaces.

→ Examples include restrooms that use exhaust fans to draw in conditioned air to maintain thermal conditions and atria that rely on natural convection flow to maintain thermal conditions.

→ Consider Conditioned spaces can be further classified by the following definitions:

Cooled space: An enclosed space within a building that is intentionally cooled to maintain the thermal conditions below the maximum criteria.

Heated Space: An enclosed space within a building that is intentionally heated to maintain the thermal conditions above the minimum criteria

(4.2) PASSIVE SOLAR CONCEPTS

→ Passive building concepts

→ Passive solar design refers to the use of the sun's energy for the heating and cooling of living spaces by exposure to the sun.

→ When sunlight strikes a building, the building materials can reflect, transmit or absorb the solar radiation.

→ In addition, the heat produced by the sun causes air movement that can be predictable in designed spaces.

→ These basic responses to solar heat lead to design elements, material choices and placement that can provide heating and cooling effects in a home.

→ Unlike active solar heating systems, passive systems are simple and do not involve substantial use of mechanical and electrical devices, such as pumps, fans, or electrical control to move the solar energy.

HEATING

The goal of passive solar heating systems is to capture the sun's heat with in the building's elements and to release that heat during periods when the sun is absent, while also maintaining a comfortable room temperature.

→ The two primary elements of passive solar heating are south facing glass and thermal mass to absorb, store, and distribute heat.

→ There are several different approaches to implementing those elements.

DIRECT GAIN

The actual living space is a solar collector, heat absorber and distribution system.

- South facing glass admits solar energy into the house where it strikes masonary floors and walls, which absorb and store the solar heat, which is radiated back into the room at night.
- These thermal mass materials are typically dark in colour in order to absorb as much heat as possible.
- The thermal mass also tempers the intensity of the heat during the day by absorbing energy.
- Water containers inside the living space can be used to store heat.
- However, unlike masonary water requires carefully designed structural support, and thus it is more ~~different~~ difficult to integrate into the design of the house.
- The direct gain system utilizes 60-75% of the sun's energy striking the windows.

→ For a direct gain system to work well, thermal mass must be insulated from the outside temperature to prevent collected solar heat from dissipating.

→ Heat loss is especially likely when the thermal mass is in direct contact with the ground or with outside air that is at a lower temperature than the desired temperature of the mass.

INDIRECT GAIN

Thermal mass is located between the sun and the living space.

→ The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction.

→ The indirect gain system will utilize 30-45% of the sun's energy striking the glass adjoining the thermal mass.

→ The most common indirect gain system is Trombe wall.

→ The thermal mass, a 6-18 inch thick masonary wall, is located immediatly behind south facing glass of single or double layer, which is mounted about 1 inch or less in front of the wall's surface.

→ Solar heat is absorbed by the wall's dark colored outside surface and stored in the wall's mass, where it radiates into the living space.

→ Solar heat migrates through the wall, reaching it's rear surface in the late afternoon or early evening.

→ When the indoor temperature falls below that of the wall's surface, heat is radiated into the room.

→ Operable vents at the top and bottom of a thermal storage wall permit heat to convect between the wall and the glass into the living space.

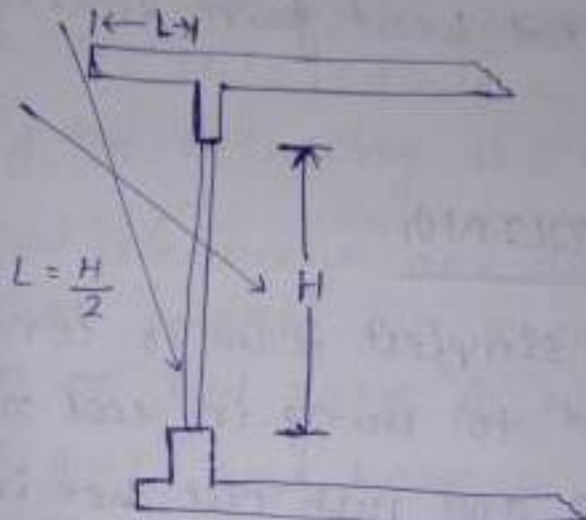
→ When the vents are closed at night radiant heat from the wall heats the living space.

PASSIVE SOLAR COOLING

Passive solar cooling systems work by reducing unwanted heat gain during the day, producing non-mechanical ventilation, exchanging warm interior air for cooler exterior air when possible, and storing the coolness the night to moderate warm daytime temperature

→ At their simpliest, passive solar cooling systems include overhangs or shades on south facing windows, trees, thermal mass and ventilation.

SHADING



(over hang design of shading)

→ To reduce unwanted heat gain in the summer, all windows should be shaded by an over-hang or other device such as awnings shutters and trellises.

→ If an awning on a south facing window protrudes to half of a window's height, the sun's rays will be blocked during the summer, yet will still penetrate into the house during the winter.

→ The sun is low on the horizon during sunrise and sunset, so over-hangs on east and west facing windows are not as effective.

→ Try to minimize the no. of east and west facing windows if cooling is a major concern.

→ Vegetation can be used to shade such windows.

→ Landscaping in general can be used to reduce unwanted heat gain during the summer.

CONVECTIVE COOLING

→ The oldest and simplest form of convective cooling is designed to bring in cool night air from the outside and push out hot interior air.

→ If there are prevailing nighttime breezes, then high vent or open on the leeward side (the side away from the wind) will let the hot air near the ceiling escape.

→ Low vents on the opposite side (the side towards the wind) will let cool night air sweep into replace the hot air.

→ At sites where there aren't prevailing breezes it's still possible to use convective cooling by creating thermal chimneys.

→ Thermal breezes, then high vent or open on the leeward side (the side away from the wind) will let the hot air near the ceiling escape.

→ Low vents on the opposite side (the side towards the wind) will let cool night air sweep in to replace the hot air.

→ At sites where there aren't prevailing breezes, it's still possible to use convective cooling by creating thermal chimneys.

→ Thermal chimneys are designed around the fact that warm air rises, they create a warm or hot zone of air (often through solar gain) and have a high exterior exhaust outlet.

→ The hot air exits the building at the high vent, and cooler air ~~in~~ is drawn in through a low vent.

(4.3) CONSTRUCTION OF SOLAR CONCENTRATORS

→ Solar concentrators are devices that work on the basic principle of focusing the sun.

→ Discover different solar concentrator technologies, including Fresnel lenses, parabolic mirrors, reflectors and luminescent concentrators.

HOW DO SOLAR ENERGY CONCENTRATORS WORK?

→ Solar concentrators are devices that work on the basic principle of focusing the sun.

→ Generally, intense sunlight results in higher temperature, which increases the rate at which heat can be efficiently converted into electricity.

→ To intensify sunlight, solar energy concentrators that bundle the sun into one focal point are used.

OPERATION OF SOLAR ENERGY CONCENTRATORS

→ Solar energy concentrators operate on the principle of focusing a bundle of sunlight onto a small surface usually with the help of an optical device or a mirror.

→ For the concentration technology to be efficient, the concentrator has to be directly facing the sun.

→ As such, there is need for the concentrators to follow the sun, with the help of a tracker, to ensure they catch maximum irradiance during the ~~sky~~ day.

SOLAR CONCENTRATOR TRACKING

→ Tracking can be single axis from east to west to cater for daily movement of the sun across the sky, and dual axis from East to South West and north to south to exactly track the changing path of the sun.

→ Since solar energy concentrators only work with direct sunlight, they are limited to clear sunny locations

ADVANTAGES OF SOLAR CONCENTRATORS

→ Using concentrated photovoltaic (CPV) technology in a solar system can have several advantages over regular si Monocrystalline and thin film technologies

* Less solar cell material is required to capture the same or even more amount of radiation as a non-concentrating energy system:

* High efficiency multijunction cells are more expensive than standard si solar cells, however due to sunlight concentration they require only a small cell surface.

→ The entire system can be cost effective due to fewer cell material, low cost optics and increased output.

Types of Solar Energy Concentrators

Fresnel Lens

The Fresnel lens is named after the designer French Physicist Augustin-jean Fresnel.

→ This front of lens is not smooth but has a rough surface sections angled differently to increase concentration while bringing weight and thickness to a minimum.

→ Fresnel lenses can either be circular, providing a point focus with high concentration power, or cylindrical providing a line focus with reduced concentration power.

PARABOLIC MIRRORS

→ The concentration setup with parabolic mirrors requires two mirrors; a collector and a concentrator.

→ The first mirror (collector) reflects the incoming rays of sunlight to a focal point in the second (concentrator) mirror, which is smaller.

→ The concentrator then directs the sun rays into the middle of the reflector mirror where the solar cell is located.

→ This configuration does not require optical lenses.

REFLECTORS

Concentrator reflectors are straight mirrors with silicon covered metal that are angled to capture sunlight rays.

→ To prevent reflection loses, the mirrors are used in pairs.

→ The angle of inclination depends on the latitude of the installation.

LUMINESCENT CONCENTRATOR

→ Luminescent concentrators rebreak light in a luminescent film and then channel it to a solar cell.

→ They do not require mirrors and optical lenses and can concentrate diffuse light.

→ The concentrator technology does not need tracking.

(4.4) ENERGY LOSSES

(1) SOLAR PANELS (conversion loss)

→ The basic function of the solar panel is to convert the sunlight into the DC electrical energy.

→ Not all the sunlight falling on the panel, is converted into the DC electrical energy, some fraction of it is either reflected back or gets dissipated as heat into the surroundings.

→ In noon time and the clear sky, a solar panel of $1m^2$, lying on the earth's surface receives arond 1,000 watts of solar power.

→ It is able to convert a small percentage, say 18%, efficiency of solar panel, of the solar power into electrical power.

→ The remaining 82% of the energy is either reflected back or dissipated as heat into the surroundings.

(2) Battery (conversion loss)

→ When you are not using energy from the solar panels to run your electrical appliances, the energy ges stored in the solar batteries in the form of chemical energy which later on can be utilized to run the appliences, when there is no sunlight or during night.

→ The battery provides energy by converting the stored chemical energy into DC electrical energy and there occurs a loss in this conversion.

→ If your battery is 85% efficient then it will convert 85% of its stored chemical energy into DC electrical energy.

(3) INVERTER (CONVERSION LOSS)

→ The energy after getting converted into DC electrical energy by the solar panels is passed through the inverter.

→ The basic function of the inverter is to convert a DC electrical energy into AC electrical energy. This is a conversion of energy from one form into the other.

→ Suppose your inverter is 95% efficient, means that it is able to convert 95% of the input DC electrical energy into AC electrical energy.

(4) WIRES (Transfer loss)

→ The energy that we receive as the output and which runs our electrical appliances needs a medium to travel from one point to the other point and this medium is provided through wires.

→ The different components of the solar power system are connected through copper wires. When the energy travels through a wire, some of it gets lost as a heat into the surroundings.

-> The longer is the distance between the solar panel and your electrical appliences, the more is the wastage of energy as heat.

(5) ENVIRONMENTAL LOSSES

Shading-

-> When your solar panels are placed under shade, they get less sunlight and in turn they produce less current.

-> Try to install your panels with no nearby high structure or tree, I am calling it an obstacle.

-> Because at one point in a day, the obstacle comes in between the sun and the panel in such a way that its shadow covers portion of the panels and block the sunlight.

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Chapter-5

SOLAR THERMAL POWER PLANTS

5.1 INTRODUCTION

→ Solar thermal power plants are electricity generation plants that utilize energy from the Sun to heat a fluid to a high temperature

→ This fluid then transfers its heat to water, which then becomes superheated steam.

→ This steam is then used turn turbines in a power plant, and this mechanical energy is converted into electricity by a generator.

→ This type of generation is essentially the same as electricity generation that uses fossil fuels, but instead heats steam using sunlight instead of combustion of fossil fuels.

→ These systems use solar collectors to concentrate the Sun's rays on one point to achive appropriately high temperature.

→ There are two types of systems to collect solar radiation and store it: passive systems are active systems.

→ Solar thermal power plants are considered active systems.

→ These plants are designed to operate using only solar energy, but most plants can use fossil fu combustion to supplement output when needed.

(5.2) SOLAR COLLECTION SYSTEM

SOLAR COLLECTORS

→ A solar collector is a device that collects and/or concentrates solar radiation from the sun.

→ These devices are primarily used for active solar heating and allow for the heating of water for personal use.

→ These collectors are generally mounted on the roof and must be very sturdy as they are exposed to a variety of different weather conditions.

→ The use of these solar collectors provides an alternative for traditional domestic water heating using a water heater, potentially reducing energy costs over time.

→ As well as in domestic settings, a large number of these collectors can be combined in an array and collectors can be combined in an array and used to generate electricity in solar thermal power plants.

TYPES OF SOLAR COLLECTORS

→ There are many different types of solar collectors, but all of them are constructed with the same basic premise in mind.

→ In general, there is some material that is used to collect and focus energy from the sun and use it to heat water.

→ The simplest of these devices uses a black material surrounding pipes that water flows through.

→ The black material absorbs the solar radiation very well, and as the material heats up the water it surrounds.

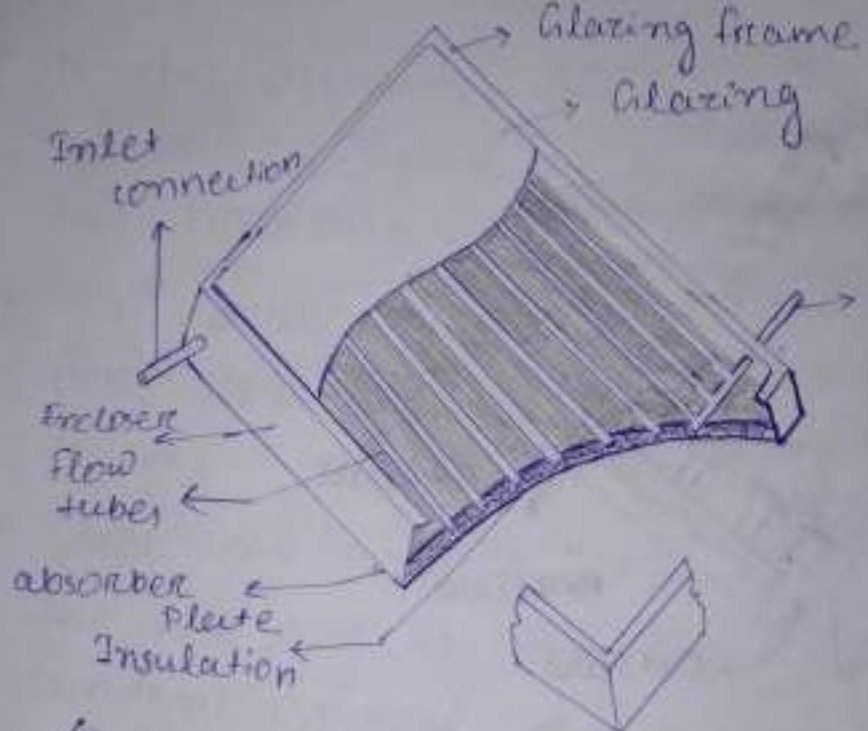
→ This is a very simple design, but collectors can get very complex.

→ Absorber plates can be used if a high temperature increase isn't necessary, but generally devices that use reflective materials to focus sunlight result in a greater temperature increase.

FLAT PLATE COLLECTORS

→ These collectors are simply metal boxes that have some sort of transparent glazing as a cover on top of a dark colour absorber plate

→ There sides and bottoms of the collector are usually covered with insulation to minimize heat losses to other parts of the collector.



(A diagram of a flat plate solar collector)

→ Solar radiation passes through the transparent glazing material and heats the absorber plate.

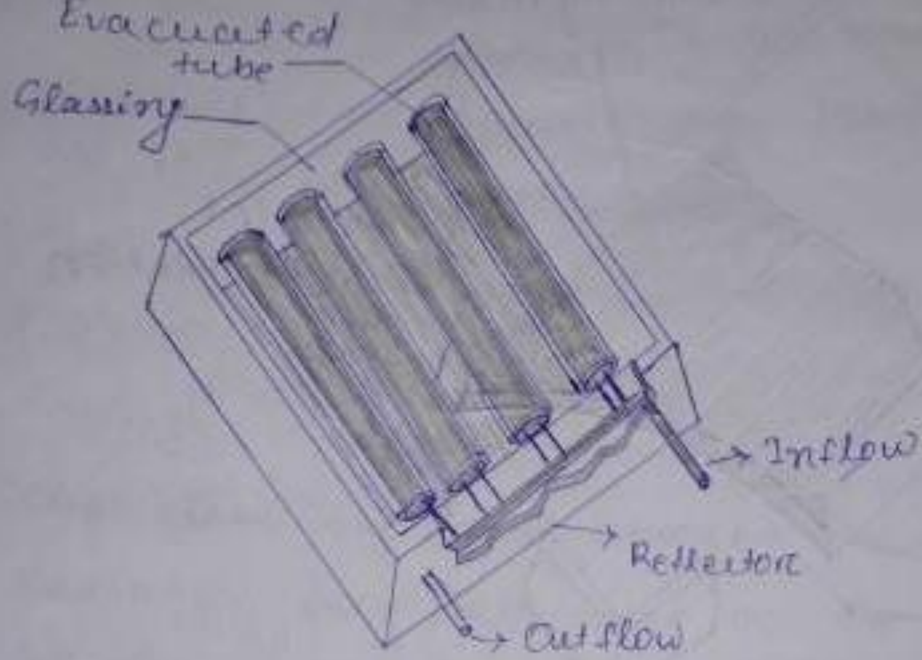
→ This plate heats up, transferring the heat to either water or air that is held between the glazing and absorber plate.

→ Sometimes these absorber plates are painted with special coating designed to absorb and retain heat better than traditional black paint.

→ These plates are usually made out of metal that is a good conductor - usually copper or aluminium.

EVACUATED TUBE COLLECTOR

EVACUATED TUBE COLLECTORS



(A diagram of an evacuated tube solar collector)

→ This type of solar collectors uses a series of evacuated tubes to heat heat water for use.

→ These tubes utilize a vacuume or a evacuate space, to capture the suns energy while minimizing the loss of heat to the surroundings.

→ They have an inner metal tube which acts as the absorber plate, which is connected to a heat pipe to carry the heat collected from sun to the water.

→ This heat pipe is essentially a pipe where the fluid contents are under a very perticular pressure.

→ At this pressure, the "hot" end of the pipe has boiling liquid in it while the "cold" end has condensing vapour.

→ This allows the theremal energy to move more efficiently from one end of the pipe to the other.

→ Once the heat from the sun moves from the hot end of the heat pipe to the condensing end, the theremal energy is transported into the water being heated for use.

LINE FOCUS COLLECTORS

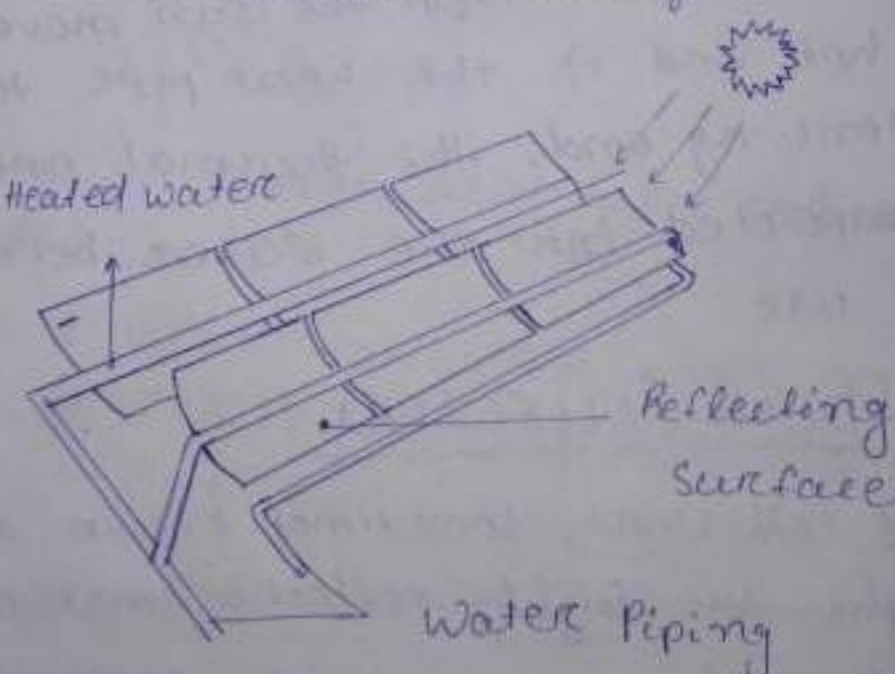
→ These collectors, sometimes known as parabolic troughs, use highly reflective materials to collect and concentrate the heat energy from solar radiation.

→ These collectors are composed of parabolically shaped reflective sections connected into a long trough.

→ A pipe that carries water is placed in the center of this trough so that sunlight collected by the reflective material is focused onto the pipe, heating the contents.

→ These are very high powered collectors and are thus generally used to generate steam for solar thermal power plants and are not used in residental applications.

→ These troughs can be extremely effective in generating heat from the sun, perticularly those that can pivot, tracking the sun in the sky to ensure maximum sunlight collection.



(A diagram of a line focus solar collector)

POINT FOCUS COLLECTORS

→ These collectors are large parabolic dishes composed of some reflective material that focus the Sun's energy onto a single point.

→ The heat from these collectors is generally used for driving stirling engines.

→ Although very effective at collecting sunlight, they must actively track the sun across the sky to be of any value.

→ These dishes can work alone or be combined onto an array to gather even more energy from the sun.

→ Point focus collectors and similar apparatuses can be utilized to concentrate solar energy for use with concentrate photovoltaics.

→ In this case, instead of producing heat, the sun's energy is converted directly into electricity with high efficiency photovoltaic cells designed specifically to harness concentrated solar energy.

(5.3) THERMAL STORAGE FOR SOLAR POWER PLANTS

→ In a concentrating solar power (CSP) system the sun's rays are reflected onto a receiver, which creates heat that is used to generate electricity that can be used immediately or stored for later use.

→ This enables CSP systems to be flexible, or dispatchable, options for providing clean, renewable energy.

→ Several sensible thermal energy storage technologies have been tested and implemented since 1985.

→ These include the two-tank direct system, two-tank indirect system, and single-tank thermocline system.

TWO-TANK DIRECT SYSTEM

→ Solar thermal energy in this system is stored in the same fluid used to collect it.

→ The fluid is stored in two tanks - one at high temperature and the other at low temperature.

→ Fluid from the low-temperature ~~the~~ tank flows through the solar collector or receiver, where solar energy heats it to a high temperature, and it then flows to the high-temperature tank for storage.

→ Fluid from the high-temperature tank flows through a heat exchanger, where it generates steam for electricity production.

→ The fluid exits the heat exchanger at a low temperature and returns to the low-temperature tank.

→ Two-tank direct storage was used in early parabolic ~~through~~ trough power plants (such as Solar Electric Generating station I) and at the solar Two power tower in california.

→ The trough plants used mineral oil as ~~fluid~~ the heat-transfer and storage fluid; Solar Two used molten salt.

TWO-TANK INDIRECT SYSTEM

→ Two-tank indirect systems function in the same way as two-tank direct systems, except different fluids are used as the heat-transfer and storage fluids.

→ This system is used in plants in which the heat-transfer fluid is too expensive or not suited for use as the storage fluid.

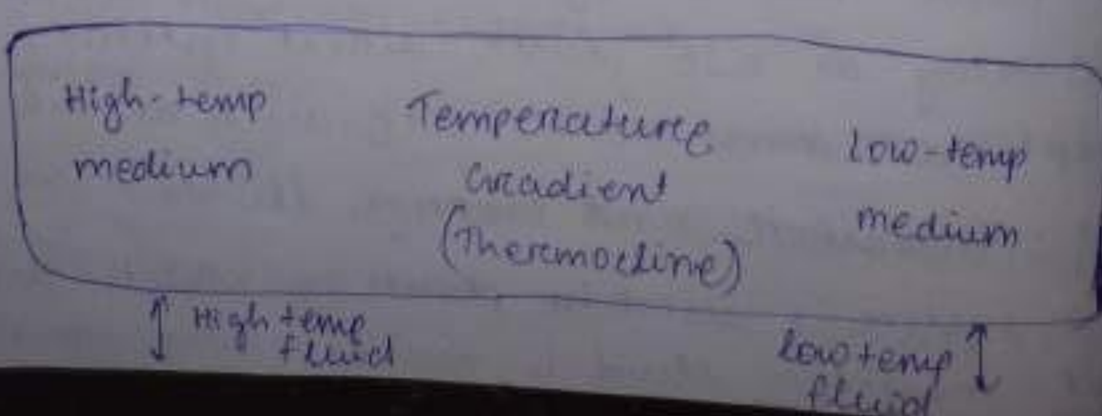
→ The storage fluid from the low-temperature tank flows through an extra heat exchanger, where it is heated by the high-temperature heat transfer fluid.

→ The high-temperature storage fluid then flows back to the high temperature storage tank.

→ The fluid exits this heat exchanger at a low temperature and returns to the solar collector or receiver, where it is heated back to a high temperature.

→ Storage fluid from the high-temperature tank is used to generate steam in the same manner as the two-tank direct system.

→ The indirect system requires an extra heat exchanger, which adds cost to the system.



(5.4) CAPACITY FACTOR

→ Capacity factor is defined as the resource availability both in terms of quantity and quality over a period of time of application

→ The capacity factor measures the overall utilization of a power-generation facility or fleet of generators.

→ Capacity factor is the annual generation of a power plant (or fleet of generators) divided by the product of the capacity and the number of hours over a given period.

→ In other words, it measures a power plant's actual generation compared to the maximum amount it could generate in a given period without any interruption

→ As power plants sometimes operate at less than full output, the annual capacity factor is a measure of both how many hours in the year the power plant operated and at what percentage of its entire production.

SOLAR MULTIPLE

→ Solar multiple is defined as the ratio between the thermal power produced by the solar field at the design point and the thermal power required by the power block at nominal conditions:(1) This parameter represents the solar field size related to the power block, in terms of nominal thermal power.

(5.5) ENERGY CONVERSION

→ The solar energy converted into electricity can be instantly used to power lights or many other devices.

→ Better still, it can be stored in batteries for future use.

→ Solar cells normally generate direct current (DC)-type electricity.

→ However, it can be converted into AC (alternating current) using a device known as inverter.

→ Solar energy converted into heat energy for the purpose of water heating can be utilized instantly or stored as hot water in tanks to be used later.

→ Solar energy can be broadly catagorized as active or passive solar energy depending on how they are captured and utilized.

→ In active solar energy, special solar heating equipment is used to convert solar energy to heat energy wheare as in passive solar energy the mechanical equipment is not present.

→ Active solar include the use of mechanical equipment like photovoltaic cells, solar thermal collectors or pumps and fans to trap solar energy.

→ Passive solar technologies convert solar energy to heat energy without the use of active mechanical systems.

→ It is mainly the practice of using windows, walls, trees, building placement and other simple techniques to capture or deflect the sun for use.

→ Passive solar heating is a great way to conserve energy and maximizing utilization.

-> An example of passive solar heating is what happens to your car on a hot summer day.

* How Solar energy converted to Electricity?

-> The initial step to convert solar energy to electricity is to install photovoltaic (PV) cells or solar cells.

-> Photovoltaic means light and electricity

-> These cells arrest the sun's energy and convert it into electricity.

-> These solar cells are made of materials that show photovoltaic effect, meaning when the sun rays strike the photovoltaic cell, the photons of light spook the electrons inside the cell triggering them to start flowing, ultimately producing photovoltaic effect. meaning when the sun rays strike the photovoltaic cell, electricity.