	b)	Interpret the advantages and limitations of fuel cells over conventional power generation methods.	L3	CO3	4 M
		OR			
11	a)	Describe the methods of hydrogen storage and discuss their applications in the energy sector.	L3	CO3	5 M
	b)	Interpret the principle of operation of MHD power generation with a neat diagram.	L3	CO3	5 M

Code: 23EE4501B

III B.Tech - I Semester - Regular Examinations - NOVEMBER 2025

RENEWABLE ENERGY RESOURCES
(ELECTRICAL & ELECTRONICS ENGINEERING)

Duration: 3 hours Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

PART – A

		BL	CO
1.a)	Explain solar insolation.	L2	CO1
1.b)	Classify different types of concentrating collectors.	L2	CO1
1.c)	Explain Betz's limit in Wind power.	L2	CO1
1.d)	List out main applications of wind energy.	L3	CO2
1.e)	Identify some organic materials used in bio-mass plant.	L2	CO1
1.f)	Mention two operational problems in geothermal power plants.	L2	CO1
1.g)	Explain tidal energy.	L2	CO1
1.h)	Identify two limitations of wave energy.	L2	CO1
1.i)	What are the advantages of MHD generation?	L2	CO1
1.j)	Discuss two challenges in hydrogen storage.	L2	CO1

PART – B

			BL	CO	Max. Marks
UNIT-I					
2	a)	Interpret the advantages of concentrating collectors over flat plate collectors.	L3	CO2	4 M
	b)	Explain the I-V characteristics of a solar cell and define fill factor. What is the significance of fill factor?	L4	CO4	6 M
OR					
3	a)	Interpret how solar radiation is analyzed when Incident on tilted surface.	L3	CO2	4 M
	b)	Discuss the working principle of a solar pond and elaborate on its major applications in renewable energy systems.	L3	CO2	6 M
UNIT-II					
4	a)	Discuss the nature of wind and the factors affecting the power available in the wind.	L2	CO1	5 M
	b)	Show the disadvantages of WECS and explain briefly.	L3	CO2	5 M
OR					
5	a)	Explain the operational characteristics of WECS.	L4	CO4	5 M
	b)	Interpret the site selection considerations for setting up a Wind Energy Conversion System (WECS).	L3	CO2	5 M

UNIT-III					
6	a)	Interpret the factors affecting bio-digestion and their impact on biogas production.	L3	CO3	5 M
	b)	Interpret about dry and wet fermentation process.	L3	CO3	5 M
OR					
7	a)	Describe different types of geothermal sources and their utilization in power generation.	L3	CO3	4 M
	b)	Interpret Mini hydel power plant with a neat sketch.	L3	CO3	6 M
UNIT-IV					
8	a)	Illustrate OTEC methods with neat sketches.	L3	CO3	5 M
	b)	Draw the schematic layout of a tidal powerhouse and interpret the power generation.	L3	CO3	5 M
OR					
9	a)	Interpret in brief about wave energy conversion devices.	L3	CO3	5 M
	b)	Discuss the prospects and potential of OTEC in India.	L2	CO1	5 M
UNIT-V					
10	a)	Describe the fuel cell equivalent circuit and interpret the significance of each component.	L3	CO3	6 M

PVP23

Code: 23EE4501B

III B.TECH – I SEM REGULAR EXAMINATIONS NOVEMBER 2025

RENEWABLE ENERGY RESOURCES

ELECTRICAL & ELECTRONICS ENGINEERING

SCHEME OF VALUATION

Duration : 3 hours **Max.Marks:70**

Part - A

1a)	Solar Insolation explanation	2M
1b)	Any 2 types of Concentrating collectors	2M
1c)	Betz limit representation / explanation	2M
1d)	Any 2 applications of wind energy	2M
1e)	Any 2 organic materials in biomass plant	2M
1f)	Any 2 operational problems in geothermal plants	2M
1g)	Importance / principle of tidal energy	2M
1h)	Any 2 limitations of wave energy	2M
1i)	Any 2 advantages of MHD Generation	2M
1j)	Any 2 challenges in hydrogen storage	2M

		UNIT -I	
2	(a)	Any 5 advantages of concentrating collectors over flat plate collectors	5M
	(b)	I-V Characteristics Explanation Fill Factor Significance of Fill Factor	1M 2M 1M 1M
3	(a)	Diffuse radiation explanation Direct radiation explanation	2.5M 2.5M
	(b)	Working principle of solar pond Any two major applications	3M 2M
		UNIT -II	
4	(a)	Nature of wind explanation Factors affecting power available in wind	2.5M 2.5M
	(b)	Any 5 disadvantages of WECS with explanation	5M
5	(a)	Operational characteristics of WECS explanation Representation	4M 1M
	(b)	Any 5 site selection considerations for WECS with explanation	5M
		UNIT -III	
6	(a)	Any 5 factors affecting bio digestion and their impact on bio gas production with explanation	5M
	(b)	Biomass conversion: dry fermentation any 1 method Biomass conversion: wet fermentation any 1 method	2.5M 2.5M
7	(a)	Any 5 types of geothermal sources	5M
	(b)	Explanation of Mini/Small power plant Representation	3M 2M

		UNIT -IV	
8	(a)	Open cycle explanation Open cycle sketch Closed cycle explanation Closed cycle sketch	1.5M 1M 1.5M 1M
	(b)	Schematic layout of tidal power house Power Generation	3M 2M
9	(a)	Any two wave energy conversion devices explanation Each 2.5M **NOTE: Any 2 devices may be considered**	2*2.5M 5M
	(b)	Prospects of OTEC in India Potential of OTEC in India	4M 1M
		UNIT -V	
10	(a)	Representation of Fuel cell equivalent circuit Explanation for significance of each component	3M 2M
	(b)	Any three advantages of fuel cells Any two limitations of fuel cells	3M 2M
11	(a)	Any three Methods of hydrogen storage Any two applications in energy sector	3M 2M
	(b)	Principle of operation of MHD power generation Diagram of MHD power generation	3M 2M

Code: 23EE4501B

PVP 23

III B.TECH – I SEM REGULAR EXAMINATIONS NOVEMBER 2025

RENEWABLE ENERGY RESOURCES

ELECTRICAL & ELECTRONICS ENGINEERING

KEY

Duration : 3 hours **Max.Marks:70**

PART-A

1. a) The total solar radiation received at any point on the earth's surface is the sum of the direct and diffus radiation. This is referred as the insolation at that point.

b) Parabolic trough collector, Mirror strip reflector, Fresnel lens collector, Flat plate collector with adjustabl mirrors, Compound parabolic concentrator(Any two can be considered)

c) Betz limit: Maximum power is extracted from a wind turbine when the exit velocity of air is one-third (the inlet velocity (Betz limit), giving a maximum power coefficient $Cp=16/27\approx59.3$

d) 1. Some of the most effective application is those that use energy derived directly from the wind withou further energy processing, conversion, or storage.
2.Pumping applications 3. Space heating 4. Water heating (Any two can be considered)

e) Agricultural Residues : Sugarcane bagasse, Animal Wastes: cow dung, Goat/sheep manure(Any two can b considered)

f) Operational Problems: Presence of Solid particles and non-condensable gases, land erosion, noise (Any tw can be considered)

g) Tidal energy is the renewable energy obtained from the natural rise and fall of ocean water levels caused by the gravitational pull of the Moon and the Sun and the rotation of the Earth. When tides move in and out, electricity is generated.

h) 1. The energy may have to be transported a greater distance to shore 2. There is relatively scarcity of accessible sites of large wave activity.

i) 1. High Efficiency 2. Fast Response and Quick Start-Up

j) 1. Low Energy Density 2. Safety and Material Issues

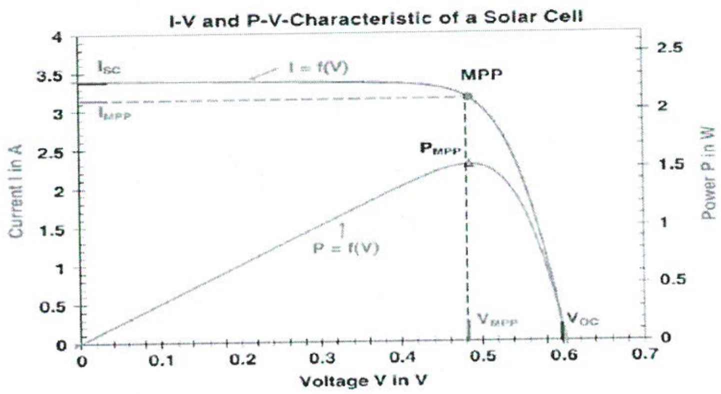
PART-B

UNIT I

2. a) The advantages of concentrating collectors over flat plate collectors are:
1. There is no need for tracking as it has high acceptance angle only seasonal adjustments are required. Foi concentration ratios of ~ 3, even seasonal adjustments may not be required.
2. The efficiency for accepting diffuse radiation is much larger than conventional concentrators.
3. By focusing sunlight onto a small receiver area, concentrating collectors reduce heat losses and achieve higher thermal efficiency.
4. Since only the small receiver area needs to be heated, less absorber material is required compared to large flat-plate collectors.
5. They perform well in regions with high direct solar radiation, delivering more useful heat compared to flat-plate collectors.

(2)

2. **b)** The I–V (current–voltage) characteristic of a photovoltaic cell represents the relationship between th output current and voltage under given conditions of illumination and temperature. When the terminals o the PV cell are short-circuited, the current reaches its maximum value, known as the short-circuit currei (Isc), which is nearly equal to the photogenerated current of the cell. As the voltage across the cell increase the current remains almost constant initially, then begins to decrease gradually, and finally drops sharply t zero at the open-circuit voltage (Voc), which is the maximum voltage the cell can provide when no current drawn. A significant point on the I–V curve is the knee point, which corresponds to the maximum powe point (MPP), where the product of current and voltage is highest, indicating the optimal operating point o the PV cell.



The ratio of the maximum obtainable power (Pmax) to the product of open-circuit voltage (Voc) and short-circuit current (Isc). A higher FF means lower internal resistive losses and better cell quality. Since the output power depends on FF, higher FF directly leads to higher efficiency of the PV module.

3. **a)** From the point of view of utilisation of solar energy we are more interested in the energy received at th earth's surface than in the extra-terrestrial energy. Solar radiation received at the surface of the earth entirely different due to the various reasons. Before studying this it is important to know the followin terms:

Beam and Diffuse Solar Radiation. The solar radiation that penetrates the earth's atmosphere and reaches th surface differs in both amount and character from the radiation at the top of the atmosphere. In the first plac part of the radiation is reflected back into the space, especially by clouds. Furthermore, the radiation entering th atmosphere is partly absorbed by molecules in the air. Oxygen and ozone (O3) formed from oxygen, absor nearly all the ultraviolet radiation, and water vapour and carbon dioxide absorb some of the energy in th infrared range. In addition, part of the solar radiation is scattered (i.e., its direction has been changed) b droplets in clouds by atmospheric molecules, and by dust particles.

Solar radiation that has not been absorbed or scattered and reaches the ground directly from the sun is calle "direct radiation" or Beam radiation. It is the radiation which produces a shadow when interrupted by an opaqu object. Diffuse radiation is that solar radiation received from the sun after its direction has been changed b reflection and scattering by the atmosphere. Because of the solar radiation is scattered in all directions in th atmosphere, diffuse radiation comes to the earth from all parts of the sky.The total solar radiation received a any point on the earth's surface is the sum of the direct and diffuse radiation. This is referred to in a gener sense as the insolation at that point. More specifically, the insolation is defined as the total solar radiation energ received on a horizontal surface of unit area (e.g., 1 sq. m) on the ground in unit time (e.g., 1 day).

3. **b)** Principle of operation and description of non-convective solar pond: A solar pond is a mass of shallow wate about 1 or 2 meters deep with a large collection area, which acts as a heat trap. It contains dissolved salts to generat a stable density gradient. Part of the incident solar radiation entering the pond surface is absorbed throughout th depth and the remainder which penetrates the pond is absorbed at the black bottom. If the pond were initially fille with fresh water, the lower layers would heat up, expand and rise to the surface. Because of the convective mixin

and heat loss at the surface, only a small temperature rise in the pond could be realized. On the other hanc convection can be eliminated by initially creating a sufficiently strong salt concentration gradient. In this cas thermal expansion in the hotter lower layers is insufficient to destabilize the pond. With convection suppressed, th heat is lost from the lower layers only by conduction. Because of the relatively low conductivity, the water acts a an insulator.

Applications of Solar Ponds

A solar pond is a large-scale solar energy collector that stores solar radiation as thermal energy in the lower laye of a salt-gradient pond. The stored heat can be used for various thermal and power applications.

1. **Process Heating**

- Solar ponds supply low-grade thermal energy (50°C–90°C) for industrial process heating.
- Used in industries like textiles, food processing, paper, and chemical plants for drying, washing, and pre-heatin operations.

2. **Power Generation**

- The stored thermal energy in the lower convective zone can be used to generate electricity through a low temperature Rankine cycle.
- Working fluids such as Freon, toluene, or ammonia–water mixtures are used in the cycle.

3. **Desalination of Water**

- The heat extracted from the solar pond is used in multi-effect or single-effect distillation systems for producin fresh water from saline water.
- Particularly useful in coastal and arid regions.

4. **Space Heating and Cooling**

- Solar ponds can provide hot water for space heating in cold climates.
- When integrated with absorption refrigeration systems, they can also be used for space cooling.

5. **Greenhouse Heating and Aquaculture**

- Maintains suitable temperature in greenhouses, fish ponds, and shrimp farms during cold seasons.

Promotes continuous productivity in agricultural and aquaculture operations

UNIT II

4. **a) The nature of the wind:**

The circulation of air in the atmosphere is caused by the non-uniform heating over water. In coastal regior this manifests itself in a strong onshore wind. At night the process is reversed because the air cools down mo rapidly over the land and the breeze therefore blows off shore.

The main planetary winds are caused in much the same way: Cool surface air sweeps down from the poles forcin the warm air over the tropics to rise. But the direction of these massive air movements is affected by the rotation c the earth and the net effect is a large countries-clockwise circulation of air around low pressure areas in the norther hemisphere and clockwise circulation in the southern hemisphere. The strength and direction of these planetar winds change with the seasons as the solar input varies. Despite the wind's intermittent nature, wind patterns at an particular site remain remarkably constant year by year. Average wind speeds are greater in hilly and coastal are than they are well inland. The winds also tend to blow more consistently and with greater strength over the surfac of the water where there is a less surface drag.

Wind speeds increase with height. They have traditionally been measured at a standard height of ten metres whe

they are found to be 20-25% greater than close to the surface. At a height of 60 m they may be 30-60% high
because of the reduction in the drag effect of the earth's surface.

Three factors determine the output from a wind energy converter:

(i) the wind speed;

(ii) the cross-section of wind swept by rotor; and

(iii) the overall conversion efficiency of the rotor, transmission system and generator or pump.

No device, however well-designed, can extract all of the wind's energy because the wind would have to b brought to a halt and this would prevent the passage of more air through the rotor. The most that is possible is fo the rotor to decelerate the whole horizontal column of intercepted air to about one-third of its free velocity. A 100% efficient aerogenerator would therefore only be able to convert up to a maximum of around 60% of the availabl energy in wind into mechanical energy. Well-designed blades will typically extract 70% of the theoretic maximum, but losses incurred in the gearbox, transmission system and generator or pump could decrease overa wind turbine efficiency to 35% or loss.

The power in the wind can be computed by using the concept of kinetics. The wind mill works on the principle o converting kinetic energy of the wind to mechanical energy. We know that power is equal to energy per unit tim The energy available is the kinetic energy of the wind. The kinetic energy of any particle is equal to one half i mass times the square of its velocity, or 1/2 mV2. The amount of air passing in unit time, through an area A, wi velocity V, is A.V, and its mass m is equal to its volume multiplied by its density p of air.

4. **b) Disadvantages of WECS**

1. Intermittent / variable energy source: Wind speeds vary with time; there are periods of low or zero wind, s generation is not steady.
2. High initial capital cost: Turbines, foundations, control systems, grid connection, site surveys, and civil work make up large up-front investment.
3. Site constraints: Good sites (with steady, high-speed winds) are often in remote or difficult terrain, whic increases civil, transmission, and logistics costs.
4. Aesthetic, noise and environmental concerns: Blades generate noise; turbines may be considered visuall intrusive; and there is collision risk to birds and bats.
5. Grid integration challenges / power quality: Fluctuating output makes maintaining stable voltage and frequenc more complex; may require storage or auxiliary backup.
6. Maintenance, wear, and reliability: Moving parts (bearings, gearboxes, blades) are prone to fatigue, wear, an occasional failure. Extreme weather (storms, lightning) can damage turbines.
7. Lower efficiency / energy losses: Conversion losses in gearboxes, transmission, aerodynamic inefficiencies, an system losses reduce overall efficiency.
8. Land / social constraints: Though the base is small, the spread of a wind farm may face objections fro communities or compete with land use (e.g. forests, scenic areas).

5. **a)** Wind possesses energy by virtue of its motion. Any device capable of slowing down the mass of moving ai like a sail or propeller, can extract part of the energy and convert is into useful work. Three factors determine th output from a wind energy converter:

(i) the wind speed;

(ii) the cross-section of wind swept by rotor; and

(iii) the overall conversion efficiency of the rotor, transmission system and generator or pump.

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$$\text{Available wind power } P_a = \frac{1}{2}\rho\frac{\pi}{4}D^2V^3 \text{ watts}$$

$$= \frac{1}{8}\rho\pi D^2V^3 \qquad \ldots(6.3)$$

The equation tells us that the maximum power available from the wind varies according to the square of the diameter of the intercept area (or square of the rotor diameter), normally taken to be swept area of the aeroturbine. Thus doubting the diameter of the rotor will result in a four-fold increase in the available wind power. Equation (6.3) gives us in sight into why the designer of an aeroturbine for wind electric use would place such great emphasis on the turbine diameter. The combined effects of wind speed and rotor diameter variations are shown in. Fig. 6.1. Wind machines intended for generating substantial amounts of power should have large rotors and be located in areas of high wind speeds. Where low or moderate powers are adequate, these requirements can be relaxed.

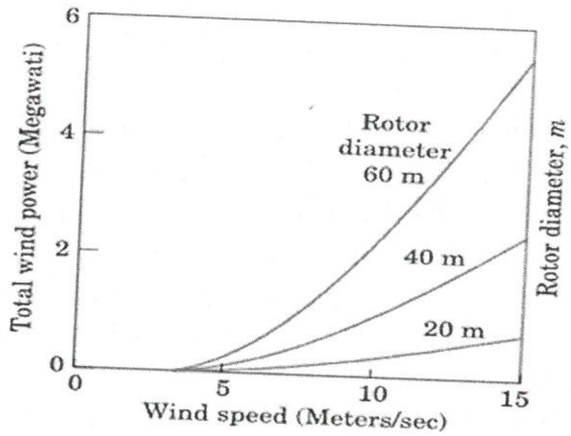


Fig. 6.1. Dependence of wind-rotor power on wind speed and rotor diameter.

5. **b) Site selection considerations**

The power in the wind increases rapidly with the speed. The site choice for a single or a spatial array of WEC (wind energy conversion system) is an important matter when wind electrics is looked at from the systems point ‹ view of aero turbine generators feeding power into a conventional electric grid. Technical, economi environmental, social, and other factors are examined before a decision is made to erect a generating plant on specific site. Some of the main considerations are discussed below.

(1) High annual average wind speed: The fundamental requirement to the successful use of WECS, obviously, an adequate supply of wind as stated above. The wind velocity is the critical parameter. The power in the wind l through a given cross-sectional area for a uniform wind velocity V, is

$$P_{,,} = KV3$$

where, K is a constant. It is evident, because of the cubic dependence on wind velocity that small increases in markedly affect the power in the wind, e.g., doubling V, increases P by a factor of 8. It is obviously desirable t select a site for WECS with high wind velocity. Strategy for siting is generally recognized to consists of:

(i) Survey of historical wind data,

(ii) Contour maps of terrain and wind are consulted.

(iii) Potential sites are visited.

(iv) Best sites are instrumented for approximately one year.

(v) Choose optimal site.

(2) Availability of anemometry data.: It is another important siting factor. The principal object is to measure th wind speed which basically determines the WECS output power. The anemometer height above ground, accurac linearity, location on the support tower, shadowing and inaccurate readings therefrom, icing inertia of rotor wheth it measures the horizontal velocity component or vertical, and temperature effects are a few of the many difficultie encountered.

(3) Wind structure at the proposed site: The ideal case for the WECS would be a site such that the V curve wa flat, i.e., a smooth steady wind that blows all the time; but a typical site is always less than ideal. Wind especiall near the ground is turbulent and gusty, and changes rapidly in direction and in velocity. This departure fro homogeneous flow is collectively referred to as "the structure of the wind."

(4) **Altitude of the proposed site**: It affects the air density and thus the power in the wind and hence the usef WECS electric power output. Also, as is well known, the winds tend to have higher velocities at higher altitude One must be careful to distinguish altitude from height above ground. They are not the same except for a sea lev WECS site.

(5) **Terrain and its aerodynamic**: One should know about terrain of the site to be chosen. If the WECS is to b placed near the top but not on the top of a not too blunt hill facing the prevailing wind, then it may be possible t obtain a 'speed up' of the wind velocity over what it would otherwise be

(6) **Local Ecology**: If the surface is bare rock it may mean lower hub heights hence lower structure cost. If trees o grass or vegetation are present, all of which tend to destructive the wind, then higher hub heights will be neede resulting in larger system costs than the bare ground case.

(7) Distance, to Roads or Railways: This is another factor the system engineer must consider for heavy machiner structures, materials, blades and other apparatus will have to be moved into any chosen WECS site.

(8) **Nearness of site to local centre/users.**: This obvious criterion minimizes transmission line length and henc losses and costs. After applying all the previous siting criteria, hope fully as one narrows the proposed WECS sit to one or two they would be relatively near to the users of the generated electric energy.

(9) **Nature of ground**. Ground condition should be such that the foundations for a WECS are secured. Groun surface should be stable. Erosion problem should not be there, as it could possibly later wash out the foundations o a WECS, destroying the whole system.A site should have a high annual wind speed.

UNIT III

6.a) Factors affecting Bio digestion:

The following are the factors that affect generation of biogas:

(1) pH or the hydrogen-ion concentration
(2) Temperature
(3) Total solid content of the feed material
(4) Loading rate
(5) Seeding
(6) Uniform feeding
(7) Diameter to depth ratio
(8) Carbon to Nitrogen ratio
(9) Nutrients
(10) Mixing or stirring or agitation of the content of the digester
(11) Retentation time or rate of feeding
(12) Type of feed stocks
(13) Toxicity due end product
(14) Pressure
(15) Acid accumulation inside the digester.

1. *pH or hydrogen ion concentration.* pH of the slurry changes at various stages of the digestion. In the initial aci formation stage in the fermentation process, the pH is around 6 or less and much of CO_2 is given off. In the latte 2-3 weeks time, the pH increases as the volatile acid and N_2 compounds are digested and CH_4 is produced. T maintain a constant supply of gas, it is necessary to main tain a suitable pH range in the digester.

The digester is usually buffered if the pH is maintained between 6.5 to 7.5. In this pH range, the micro-organism will be very active and biodigestion will be very efficient. If the pH range is between 4 and 6 it is called acidic. If is between 9 and 10 it is called alkaline.

2. *Temperature.* Methane bacteria work best at a temperature of between 35° to 38°C. The fall in gas productio starts at 20°C and stops at a temperature of 10°C. At one experiment 2.25 cu m of gas was produced from 4.25 m

of cattle dung everyday when the digester temperature was 25°C. When the temperature was raised to 28.3°C, th gas production increased by 50% to 3.75 cum/day.

In addition to ambient temperature, other weather conditions also influence the gas generation *viz.*

(a) Wind velocity (chill factor)

(b) Sun shine directly available to keep the dome at the optimum temperature.

(c) Type of food given to cattle (in case of Gobar gas generation).

3.Total Solid Content: The cow dung is mixed usually in the proportion of 1 : 1 (by weight) in order to bring the total solid content to 8-10%. The raw cowdung contains 80-82% of moisture. The balance 18-20% is termed as total solids.

4.Loading Rate: Loading rate is defined as the amount of raw material (usually kg of volatile solids) fed to the digester per day per unit volume. Most municipal sewage treatment plants operate at a loading rate of 0.5 to 1.6 kg of volatile soilds per m^3 per day. Much higher rates are possible, but as with most aspects of digesters, the optimum situation is a compromise. If a digester is loaded with too much raw material at a time, acids will accumulate and fermentation will stop.

5.Seeding: Although the bacteria required for acid fermentation and meth- ane fermentation are present in the cow dung, their numbers are not large. While the acid formers proliferate fast and increase in numbers, the methane formers reproduce and multiply slowly.

6.Uniform Feeding: One of the prerequisites of good digestion is the uniform feeding of the digester so that the micro-organisms are kept in a relatively constant organic solids concentration at all times. Therefore the digester must be fed at the same time everyday with a balanced feed of the same quality and quantity.

7.Carbon Nitrogen ratio of the input material: Besides carbon the quan- tity of N_2 present in the wastes is a crucial factor in the production ofbiogas. All living organisms require nitrogen to form their cell proteins from a biological view point, a digester is a culture of bacteria feeding upon and converting organic wastes.

8.Diameter to Depth Ratio: Research investigations reveal that gas pro- duction per unit volume of digester capacity was maximum when the diameter to depth ratio was in the range of 0.66 to 1.00. But reports from the field do not confirm this.

9.Nutrients: The major nutrients required by the bacteria in the digester are, C, H_2, 0_2, N_2, P and S, of these nutrients N_2 and Pare always in short supply and therefore to maintain proper balance of nutrients an extra raw material rich in phosphorus (night soil) and N_2 (chopped leguminous plants) should be added along with the cow dung to obtain maximum production of gas.

10.Mixing or stirring or agitation of the content of the digester: Since bacteria in the digester have very limited reach to their food, it is necessary that the slurry is properly mixed and bacteria get their food supply. In sewage treatment plants, the digesters, especially the first tank in two stage digestion, are equipped for mixing the tank contents either by sludge recirculation pumps, or gas recirculation or by using one or more deep draft tubes with propeller mixers at the bottom.

11. Retention time or rate of feeding: The period of retention of the material for biogas generatioı inside the digester is known as the retention period. This period will depend on the type of feed stocks an the temperature. Normal value of the retention period is between 30 and 45 days and in some cases 6 days. By regulating the daily feed volume, the retention time can be controlled. Periods for differeı materials to get well fermentation are: (i) Cow and buffalo dung50 days (ii) Pig-dung (iii) Poultry dropping (iv) Night soil

6. **b)** The choice of the process is determined by a number of factor the location of the resource and its physic: condition, the economics of competing processes, and the availability of a suitable market for the product. Biomass conversion, or simply bioconversion can take many forms:

(1) direct combustion, such as wood waste and bagasse (sugarcane refuge),
(2) thermochemical conversion, and
(3) biochemical conversion.

Thermochemical conversion takes two forms: gasification and liquefaction, *Gasification* takes place by heating th biomass with limited oxygen to produce low heating value gas or by reacting it with steam and oxygen at hig pressure and temperature to produce medium heating value gas. The latter may be used as fuel directly or used i liquefaction by converting it to methanol (methyl alcohol CH_3OH), or ethanol (ethyl alcohol CH_3CH_2OH) or it ma be converted to high heating value gas.

Biochemical conversion takes two forms. Anaerobic digestion and fermentation. *Anaerobic* digestion involves th microbial digestion of biomass. (An anaerobe is a micro-organism that can live and grow without air or oxygen, gets its oxygen by the decomposition of matter containing it). It has already been used on animal manure but it als possible with other biomass. The process takes place at low temperature upto 65°C, and requires a moisture content of at least 80 per cent. It generates a gas consisting mostl of CO_2 and methane (CH_4) with minimum impurities such as hydrogen sulfide. The gas can be burned directly (upgraded to synthetic natural gas by removing the CO_2 and the impurities. The residue may consists of protein ric sludge that can be used as animal feed and liquid effluents that are biologically treated by standard techniques an returned to the soil.

Fermentation is the breakdown of complex molecules in organic compound under the influence of a ferment such a yeast, bacteria, enzymes, etc. Fermentation is a well-established and widely used technology for the conversion (grains and sugar crops into ethanol. About 500 million gal ethanol per year by 1985, were produced in the limite states by the use of surplus gain. It is intended for mixing with gasoline to produce *gasohol* (90% gasoline, 10° ethanol). This process requires high cost and high energy required. One scheme considered for reducing costs (ethanol production by fermentation is in finding less expensive grains or sugars and a process that requires les energy. Glucose produced by hydrolysis of an abundant carbohydrate polymer called *ligno cellulose* is bein considered for the former.

Biomass energy concepts under study are resulting in the cultivation of large forests in areas not suitable for foo production. The trees are to be harvested by automated means, then chipped and pulverized for burning in a powe plant that would be located in the middle of the forest.

Liquefaction. Liquid yields are maximized by rapid heating of the feedstock to comparatively low temperature The vapours are condensed from the gas stream and these separate into a two phase liquor: the aqueous phas (pyroligneous acid) contains a soup of water-soluble organic materials like acetic acid, acetone and methanol ('woo alcohol'); the non-aqueous phase consists of oils and tars. These crude products can be burnt (with some difficulty but it is usually more profitable to up-grade them to premium fuels by conventional refining techniques.

Other pyrolysis products include fuel gas-essentially carbon-monoxide and hydrogen and carbon char. The gas generally burnt to maintain the temperature of the reactor; the char can be manufactured into briquetts for use a solid fuel.

Pyrolysis can also be carried out in the presence of small quantities of oxygen ('gasification'), water ('stea gasification') or hydrogen ('hydrogenation').

Gasification. Pyrolysis of wet biomass produces fuel gas and very little liquid. An alternative technique fo maximizing gas yields is to blow small quantities of air or oxygen into the reactor vessel and to increase th temperature to over 1000°C. This causes part of the feed to burn. Fuel gas from air-blown gasifiers has a lo calorific value (around 5 MJ/m3) and may contain upto 40% inert nitrogen gas overall yields of 80-85% can b expected. Fuel gas from oxygen-fed systems has a medium calorific value (10-20 MJ/m3). This gas can either b burnt or converted into substitute natural gas (methane) or methanol by standard catalytic processes. Methano yields of around 50% can be achieved from biomass.

Steam-gasification. Methane is produced directly from woody matter by treatment at high temperatures an pressures with hydrogen gas. The hydrogen can be added or, more commonly, generated in the reactor vessel fro carbon monoxide and steam. Recent analyses suggest that steam gasification is the most efficient route t methanol. Net energy yields of 55% can be achieved although higher yields are likely in the future as th technology is developed.

Hydrogenation. Under less severe conditions of temperature and pressure (300-400°C and 100 atmospheres carbon monoxide and steam react with cellulose to produce heavy oils which can be separated and refined t premium fuels.

7.a)

Geothermal sources are therefore of three basic kinds: (1) hydrothermal (2) geo pressured and (3) petro therma These will be explained later.

The total amount of energy in the outer 10 km of the earth's crust exceeds greatly that obtainable by th combustion of coal, oil and natural gas. At present, however, only the relatively small proportion of the geotherm energy in wet reservoirs (a geothermal reservoir is defined as a region where there is a concentration of extractabl heat), may be regarded as economically useful.

Historically, the first applications of geothermal energy were for space heating, cooking, and medicinal purpose The first mechanical conversion was in 1897 when the steam of the field at Larderallo, Italy, was used to heat boiler producing steam which drove a small steam engine. The first attempt to produce electricity also took plac at Larderello in 1904 with an electric generator that powered four light bulbs.

Geothermal Sources:

Five general categories (or kinds) of geothermal resources have been identified:

(1) Hydrothermal convective systems. These are again subclassified as:

(a) Vapour dominated or dry steam fields.

(b) Liquid dominated system or wet steam fields, and

(c) Hot water fields.

(2) Geopressure resources.

(3) Petro-thermal or Hot dry rocks (HDR).

(4) Magma resources.

(5) Valcanoes.

1. The hydrothermal convective systems are best resources for geothermal

Vapor dominated Systems: In these systems the water is vaporized into steam that reaches the surface in relatively dry condition at about 200°C and rarely above 7 kg/cm3 (8 bar). This steam is the most suitable for us in turbo electric power plants, with the least cost. It does, however, suffer problems similar to those encountere by all geothermal systems, namely, the presence of corrosive gases and erosive material and environment problems. These type of systems are very less in numbers; they are only five known sites in the world. Th Geysers plant in the United States, the largest in the world today, and Larderello in Italy, are both vapor-dominate systems.

Liquid dominated Systems: In these systems the hot water circulating and trapped underground is at temperature range of 175 to 315°C. When tapped by wells drilled in the right places and to the right depths, th water flows naturally to the surface or is pumped upto it. The drop in pressure, usually to 7 kg/cm2 (8 bar) or les causes it to partially flash to a two-phase mixture of low quality i.e., liquid-dominated. It contains relatively larg concentration of dissolved solids ranging between 3000 to 25,000 ppm and sometimes higher. Power production adversely effected by these solids because they precipitate and cause scaling in pipes and heat exchanger surface thus reducing flow and heat transfer. Liquid dominated systems, however, are much more plentiful than vapou dominated systems, and, next to them, require the least extension of technology.

(2) **Geopressured Systems**. These resources occur in large, deep sedimentary basins. The reservoirs contai moderately high temperature water

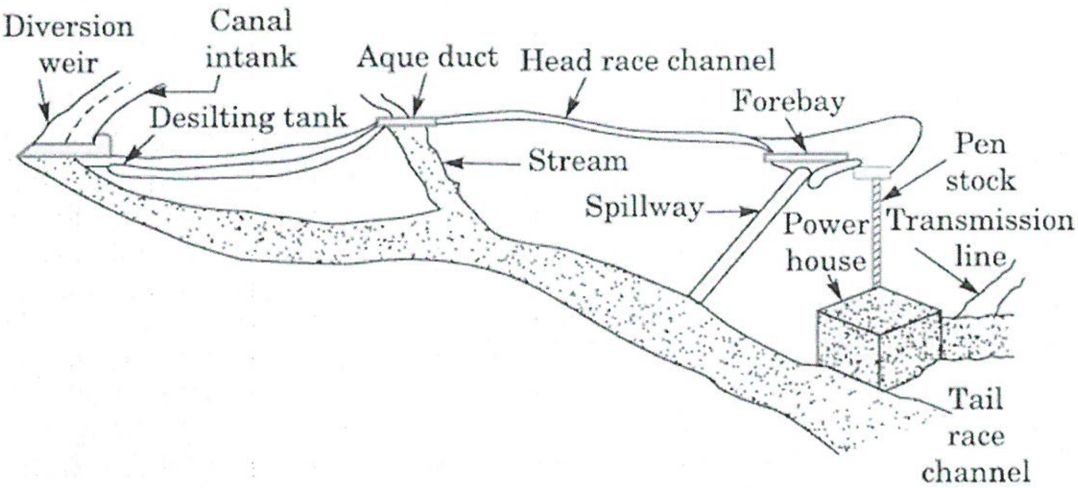
(or brine) under very high pressure. They are of special interest because substantial amounts of methane CH (natural gas) are dissolved in the pressurized water (or brine) and are released when the pressure is reduce Geopressured water is tapped

in much deeper underground acquifers (it is a water-bearing stratum of permeable rock, gravel or sand), at deptl between about 2400 to 9000 m. This water is thought to be at the relatively low temperature of about 160°C and under very high pressure, from the overlying formation above, of about 1050 kg/cm2 (more than 1000 bar). It ha a relatively high salinity of 4 to 10 per cent and is often referred to as brine. The geopressured resources are quit large: they could be used for the generation of electric power and the recovery of natural gas if suitable technolog could be developed and if individual reservoir productivity and longevity prove to be adequate.

(3) **Hot Dry Rocks (or Petrothermal Systems)**. These are very hot solid rocks occurring at moderate deptl but to which water does not have access, either because of the absence of ground-water or the low permeability o the rock (or both). In order to utilize this resource, means must be found for breaking up impermeable rock a depth, introducing cold water, and recovering the resulting hot water (or steam) for use at the surface. The know temperatures ofHDR vary between - 150 to 290°C. This energy, called petrothermal energy, represents by far th largest resource of geothermal energy of any type, as it accounts for large percent of the geothermal resourc

Much of the HDR occurs at moderate depths, but it is largely impermeable as stated above in order to extra thermal energy out of it, water will have to be pumped into it and back out to the surface. It is necessary for th heat transport mechanism that a way be found to render the
fracturing by (1) high-pressure water or (2) nuclear explosives. Efforts in this direction are in progress.
(4) **Magma Resources**. These consist of partially or completely molten rock, with temperatures in excess (650°C, which may be encountered at moderate depths, especially in recently active volcanic regions. Thes resources have a large geothermal energy content, but they are restricted to a relatively few locations. Furthermor the very high temperatures will make extraction of the energy a difficult technological problem.

7. **b) Small/mini hydel power plant: The** hydroelectric power stations with relatively low installed capacity, usually located on small rivers, streams, or irrigation canals are termed as mini / small hydel power plants. They ar designed to supply power to local communities, rural areas, or small industries.



Working Principle:
Introduction. A large potential of energy remains untapped in India in hilly streams and canal falls in the range (mini and micro hydro. The rough estimates show that the total potential in small hydro is of the order of 5000-600 MW. At present only about 3 to 4% of this potential has been utilised.
The construction for generation of about 200MW.
Civil works form a major part of the total cost of the project. Therefore, the reduction in cost of civilworks will pla a major role in reducing the overall cost of the project. The main components of civil works are diversion structure, water conductor system, desilting tank, Forebay, spillway, penstock, power house, tailrace channel and protection works. Some of these are discussed as follows:
Diversion Structure
The diversion structure provided should be simple in construction as well as economical. It should invol minimum maintenance. Depending upon the type of river bed the diversion structure may be of two types *viz* Boulder weir and Trench type weir. Boulder weir is quite cheap and is suitable where rock is encountered just belo the river bed. Where the streams carry big boulders during flood season, it may destroy the boulder type we constructed across the river. This problem can be solved by providing trench type weir. The trench type we consists of a trapezoidal trough located below the bed of the river with top kept at the bed level of the river. Th intake is located at the end of the trench weir.
It is usually constructed in reinforced concrete or masonry. A gate is also provided with the intake to release th water to the desired extent. The horizontal trash rack is provided at the bed level with slope in the down strea direction so that the water is tapped and boulders may roll down. The spacing between bars of trash racks should b so selected that it is adequate to draw that entire flow during lean period even if half of the effective area is clogge The length of the trench weir which is equal to the water way, should be adequate to pass the designed flood. Th longitudinal-slope provided in the trench weir should be adequate to develop such velocity of water that the be load entering the trench is flushed.
Water Conductor System
Water conductor system is a very important, component of the hydro power scheme. The type of water conduct system depends on the site conditions and the materials available. The design of the water conductor system shoul

ensure minimum head loss, adequate velocity of flow so that silt does not settle down. The materials of constructio should be such that the loss due to seepage is also minimized. The most commonly used channel section trapezoidal. To ensure minimum seepage, the lining of channel can be done with LDPE film. In steep hill slop RCC hume pipes are most suitable as they can be hurried in a cut and cover trench.

Desilting Tank

Desilting tank is provided usually in the initial reaches of water conductor to trap the suspended silt load an pebbles etc., so as to minimize the erosion damages to the turbine runner. The size of the silt particles to be trappe for medium head power stations is from 0.2 to 0.5 mm and for high head it is from 0.1 to 0.2 mm. The depth of tank maybe kept between 1.5 to 4 m. The horizontal flow velocity should not exceed 0.4 to 0. mis.

Penstock

Water is fed to the machines through penstocks. Design ofpenstocks involves two aspects *viz,* hydraulic design an structural design. The hydraulic design consists of determining diameter of penstock. The diameter of penstoc should also involve economic considerations. In structural design, thickness of penstock is determined. Generall the penstock are fabricated of mild steel. However PVC and RC hume pipes may also be used to reduce the cost.

Spillway

In the case of load rejection, the water level may rise and flood the area. Therefore, a spillway is provided keepin its crest at the permissible water level so that water level may not rise above the maximum permissible leve Spillway can be provided in the form of channel or pipe.

Power House Building

Power house building accommodates turbine, generator, control panels, auxiliary equipment etc. It must be a simpl structure constructed either in RCC or stone masonry. The plane size of power house building depends upon the siz and number of machines and centre to centre distance between them. This spacing should be kept minimu permissible so that size is reduced. The height of building is kept about 3-5 m. Where ever possible crane should b replaced by pulley block to make the scheme more economical. In cases where crane is provided, RCC columr may be provided to support it otherwise ordinary masonry may be used for the construction of walls. The roof ma be provided on tubular trusses to reduce the cost.

Tail Race Channel

Water after flow through machine is fed to the stream downstream of power house. It may be trapezoidal (rectangular channel constructed in stone masonry or brick masonry depending upon the material available locally.

UNIT-IV

8.a) Methods of ocean thermal electric power generation.

There are two rather different methods for harnessing ocean thermal differences. One is the open cycle, also know as the Claude cycle, and other is the closed cycle system, also known as the Anderson cycle.

Open cycle OTEC system (Claude cycle).

In the open cycle turbine system, water is the working fluid. The warm surface water is caused to boil by lowerin the pressure, without supplying any additional heat. The low pressure steam produced then drives a turbine, and th exhaust steam is condensed by the deep colder water and is discarded. A heat exchanger is not required in th evaporator, and direct contact between the exhaust steam and a cold water spray makes a heat exchanger a necessary in the condenser. On the other hand, because of the low energy content of the low pressure steam, ver large turbines or several smaller units operating in parallel would be required to achieve a useful electric pow output.

The Claude cycle or open cycle which is older one, utilizes the vapour pressure of sea water itself as the workin medium and has been demonstrated to be practicable. The other method, a. closed cycle known as the Rankir cycle, uses a working fluid with higher vapour pressure (such as ammonia, hydrocarbon or halocarbon) at th temperature available. This cycle is favored for the future development in expectation of higher efficiency. The fir published work on OTEC by d'. Arsonvol in 1881, suggests a closed cycle, and that article proposed sulfur di-oxic (SO_2) as the working fluid. However, the first OTEC experiments by Claude in the 1920s utilized on open cycl where sea water was evaporated under a partial vacuum.

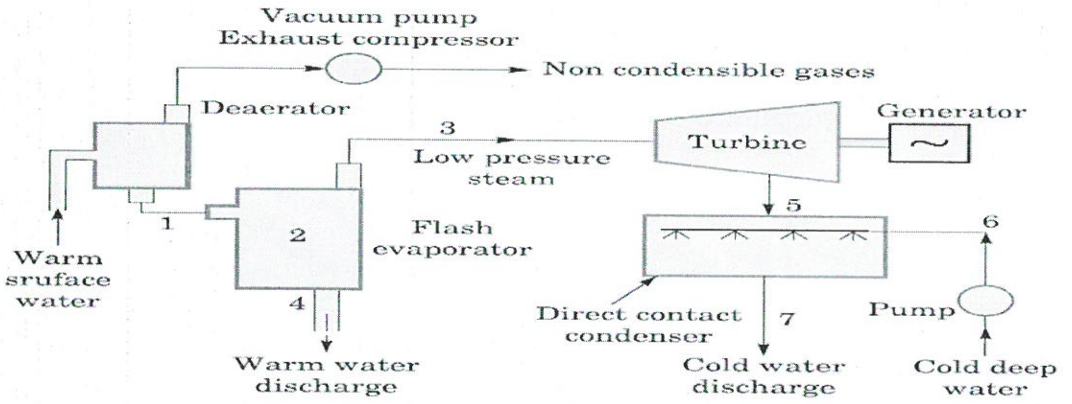


Fig. 9.1. Schematic of the OTEC open cycle.

shown in the Fig. 9.2. In the cycle shown warm surface water at say 27 °C is admitted into an evaporator in whic the pressure is maintained at a value slightly below the saturation pressure corresponding to that water temperatur At the new pressure, water which is entering the evaporator gets 'superheated'.

The cost of an open cycle system for providing substantial number of megawatts is presently regarded by mo OTEC workers as being significantly greater than for closed cycle system. The turbine cost constituted almost ha the cost of the power system, but may be amenable to reductions that could result from design innovations.

Closed or Anderson, OTEC Cycle.

In the closed cycle system, a liquid working fluid, such as ammonia or propane, is vaporized in an evaporator ((boiler); the heat required for vaporization is transferred from the warm ocean surface to the liquid by means of heat exchanger. The high pressure vapour leaving the evaporator drives an expansion turbine, similar to a stea turbine that it is designed to operate at a lower inlet pressure. The turbine is connected to an electric generator in th usual manner. The low pressure exhaust from the turbine is cooled and converted back into liquid in the condense The cooling is achieved by passing cold, deep ocean water, from a depth of 700 to 900 m or more, through a he exchanger. The liquid working fluid is then pumped back as high pressure liquid to the evaporator, thus closing th cycle.

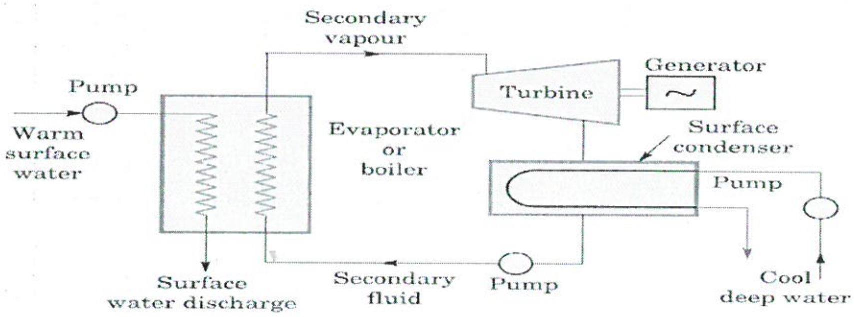


Fig. 9.3. Schematic of an OTEC closed cycle system.

fluid that receives and rejects heat to the source and sink via heat exchangers (boiler or evaporator and surfac condenser). The working fluid may be ammonia, propane, or a Freon. The operating (saturation) pressures of suc fluids at the boiler and condenser temperatures are much higher than those of water, being roughly 10 kg/cm² (= 1 bar) at the boiler, and their specific volumes are much lower, being comparable to those of steam in convention power plants. Such pressures and specific volumes result in turbines that are much smaller and hence less costl than those that use the low pressure steam of the open cycle. The closed cycle also avoids the problems of th evaporator. It however, requires the use of very large heat exchangers (boiler and condenser) because, for a efficiency of about 2%, the amounts of heat added and rejected are about 50 times the output of the plant. I addition, the temperature differences in the boiler and condenser must be kept as low as possible to allow for th maximum possible temperature difference across the turbine, which also contributes to the large surfaces of the units.

8. **b)** There are three main components of a tidal power plant i.e.
(i) The power house.
(ii) The dam or barrage (low wall) to form pool or basin.
(iii) Sluice ways from the basins to the sea and vice versa.
The turbines, electric generators and other auxiliary equipment's are the main equipment's of a power house. It is generally convenient to have the power house as well as the sluice ways in alignment with the dam.
The design cycle may also provide for pumping between the basin and the sea in either direction. If reversible pum turbines are provided, the pumping operation can be taken over at any time by the same machine. The moder tubular turbines are so versatile that they can be used either as turbines or as pumps in either direction of flow. I addition, the tubular passages can also be used as sluice ways by locking the machine to a stand still. As compare to conventional plants, this, however, imposes a great number of operations in tidal power plants. For instance, th periodic opening and closing of the sluice-ways of a tidal plant are about 730 times in a year.
Tidal power barrages have to resist waves whose shock can be severe and where pressure changes side continuously.
Since barrage length adds also to the price tag of the plant, short barrages are preferred even if basin size may hav to be smaller as a result of site choice. Up to a height of 20 m, cost remains proportional to length as it is n changed by the need to build a dam wall to withstand high hydrostatic pressure. When, the elevation exceeds the 2 m limit, costs increase faster with length. Most tidal power plants do not have heads exceeding 20 m. Because sma heads only are available, large size turbines are needed; hence, the power house is also a large structure. Both th French and Soviet operating plants use the bulb type of turbine. Of the propeller type, with reversible blades, bulb have horizontal shafts coupled to a single generator. The cost per installed kilowatt drops with turbine size, and perha larger turbines might be installed in a future major tidal power plant.

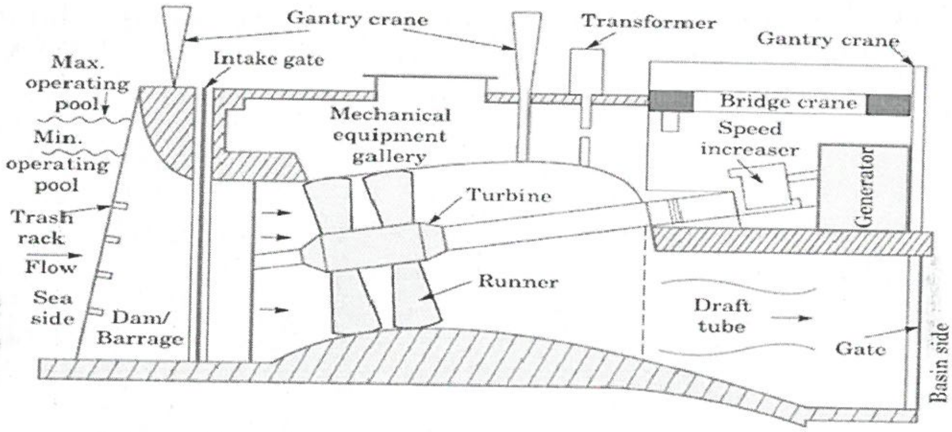


Fig. 9.9. Schematic layout of Tidal power house (Typical main unit way).

The generation of electricity from water power requires that there should be a difference in levels (or head between which water flows. A number of concepts have been proposed for generating electricity by utilizing th head that can be produced by the rise and fall of the tides to operate a hydraulic turbine. The power generation fro tides involves flow between an artificially developed basin and the sea. However in order to have a more or les continuous generation, this basic scheme can be elaborated by having two or more basins.

9. a)

The mechanical energy in waves takes different forms. There is the energy of forward motion of the wave th highly noticeable energy that slams into ships and cliffs. Some of the proposed schemes are oriented toward th forward motion kinetic energy. Any geometric arrangement that absorbs energy by converting the forwa momentum of the wave into motions of its internal parts, without reemitting as much energy as it absorbs, ca extract this forward motion energy. Also very promising from the energy extraction point of view is the potenti energy of the raised water at the wave crest.
The engineering challenge is to find a cost effective way to do it on a large scale. Since waves come in a wide rang of wave lengths and amplitudes, any effective device will either have to be broad band that is, non resonant or it wi have to have its resonance frequency continuously adjusted. Many mechanisms have been proposed, and a numb

are being investigated, For example, waves can be made to compress air in the top of floating tank, using one wa air valves. Electricity is generated as the air is bled out through a pneumatic or air turbine.

In a different devices, waves passing a pipe standing vertically in the water and equipped with an internal flop valv that allows water to move upward in the pipe but not downward, cause a water column to rise in the pipe, to a heigl many times the wave height. The water can be released from an elevated part in a controlled manner, to drive conventional hydro turbine. Another class of mechanism employs the floats with different dynamic respons characteristics. The differential motion is used to operate a pump or mechanical engine. For example, a long vertic cylinder extending far below the surface will remain nearly stationary as the waves pass by. A toroidal flo surrounding it will rise and fall with the valves, and can be made to push and pull on pump plungers attached to th cylinder.

Some of the *main concepts* for converting wave energy into mechanical or electrical are described briefly a follows:

Wave Energy Conversion by Floats

Wave motion is primarily horizontal, but the motion of the water is primarily vertical. Mechanical power is obtaine by floats making use of the motion of water. The concept visualizes a large float that is driven up and down by th water within relatively stationary guides. This reciprocating motion is converted to mechanical and then electric power is generated.

A system based on this principle is shown in Fig. 9.16, in which a square float moves up and down with the water. is guided by four vertical manifolds that are part of a platform. There are four large under water floatation tank which stabilizes the platform. Platform is supported by buoyancy forces and no vertical or horizontal displaceme occurs due to wave action. Thus the platform is made stationary in space. A piston which is attached to float a shown in figure moves up and down inside a cylinder. The cylinder is attached to platform and is therefo relatively stationary. The piston and cylinder arrangement is used as a reciprocating compressor. The downwa motion of the piston draws air into the cylinder via an inlet check valve. This air is compressed by upward motion o the piston and is supplied to the four underwater floating tanks, through an outlet check valve via the fo manifolds. In this way, the four floatation tanks serve the dual purpose of buoyancy and air storage, and also th four vertical manifolds and float guides.

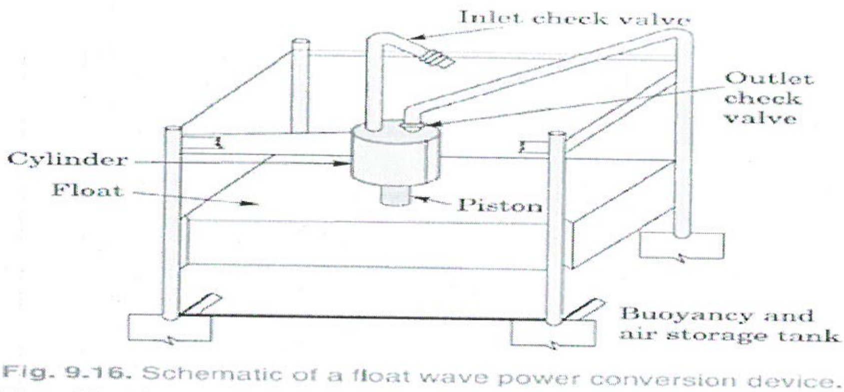


Fig. 9.16. Schematic of a float wave power conversion device.

High-Level Reservoir Wave Machine

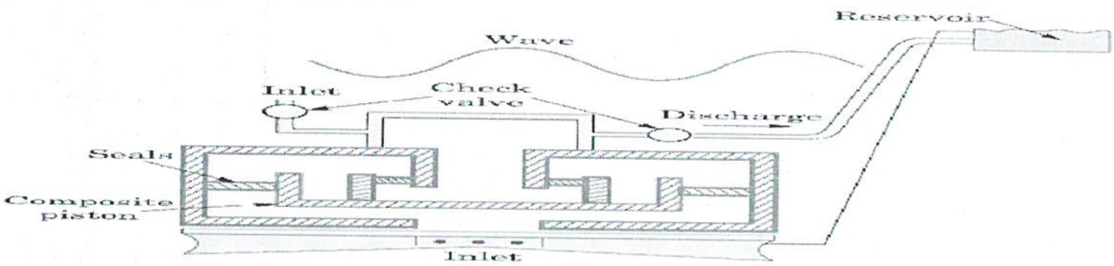


Fig. 9.17. Schematic of a high level reservoir wave machine.

The concept of this device is illustrated with reference to Fig. 9.17, in which a magnification piston is used. Th pressurized water is elevated to a natural reservoir above the wave generator, which would have to be near a sho line, or to an artificial water reservoir. The water in the reservoir is made to flow through a turbine coupled to a electric generator, and then back to sea level. Calculations made shown that a 20 m diameter generator can produc 1 MW power.

The Dolphin Type Wave Power Machine

This device uses the float which has two motions. The first is a rolling motion about its own fulcrum with th connecting rod. Revolving movements are caused between the float and the connecting rod. The other is a nearl vertical or heaving motion about the connecting rod fulcrum. It causes relative revolving movements between th connecting rod and the stationary dolphin. In both the cases, the movements are amplified and converted by gear into continuous rotary motions that drive the two electrical generators.

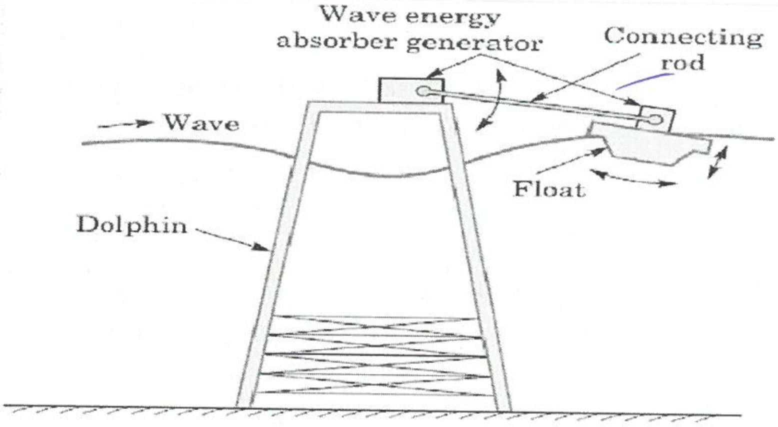


Fig. 9.18. Schematic of the Dolphin type wave generator.

Other Wave Machines

Hydraulic accumulator wave machines are also used, which instead of compressing air, the water itself pressurized and stored in a high pressure accumulator or pumped to a high level reservoir, from which it flow through a water turbine electric generator. This is done by transforming large volumes of low pressure water a wave crest into small volumes of high-pressure water by the use of a composite piston. The piston is composed of large-diameter main piston and a small-diameter piston at its center. The main piston moves up and down with th entering of the wave water through the opening. A closed water loop exists above the small piston. The pressure o the main piston is magnified on the small piston during the upstroke. The high pressure water is conducted throug a one-way valve to a hydraulic accumulator at the top of the generator. Two air (or other gas) volumes counte balance and act as cushions in a chamber above the main piston and in a sealed compartment in the hydrauli accumulator. The latter also maintains the high water pressure. Part of the high-pressure water flows through Pelton wheel or Francis hydraulic turbine that drives an electrical generator and is then discharged to a storag chamber below the turbine.

In another differential motion concept, called the "nodding duck" employs large cam shaped "ducks" mounted on very long, floating frame. The 'ducks' oscillate or 'nod' relative to the frame, driving hydraulic pumps. This 'noddin duck' scheme though only in the model testing stage, has been investigated more than most of the other concept and is currently one of the leading contenders in the British wave energy programme. It is a rather serious criticisı it was claimed bya wind power proponent that the energy pay back time for wave power systems in general and th nodding duck scheme in particular may be excessively long, owing to the large amount of steel and concre required. This claim was disputed by the inventor of the nodding duct concept.

NOTE: Any 2 devices may be considered

9, **b) Prospects of Ocean Thermal Energy Conversion in India**

The OTEC project cell established at IIT, Chennai has completed the preliminary feasibility study for establishing a 1 MW OTEC plant in Lakshadweep Island at Minicoy. The OTEC works on the principle of utilizing th temperature difference of sea water at depth and that at the surface. Both the island have large lagoons on th western side. The lagoons are very shallow with hardly any nutrient in the sea water. The proposed OTEC plant wi bring up the water from 1000 m depth which has high nutrient value. After providing cooling effect in th condenser, a part of deep sea water is proposed to be diverted to the lagoons for the development of aqua culture. hydrographic survey of the proposed site was undertaken by National Hydrographic Office, Dehradun. Th preliminary assessment of survey indicates the availability of suitable conditions for establishment of OTE plant.Potential of OTEC in India:

- Unlimited renewable energy source available 24×7 (unlike solar/wind).
- Excellent for remote islands where diesel generation is expensive.

- Can produce freshwater through desalination, which is critical for islands.
- Supports marine research and blue economy missions.

UNIT V

10. a) <u>Fuel Cell Equivalent Circuit</u>

When the cell is operating and producing current, the electrons flow through the external load to the positiv electrode; here they interact with oxygen (O2) and water (H_2O) from the electrolyte to form negatively charge hydroxyl (OH) ions; thus

$$\frac{1}{2}O_2 + H_2O + 2\bar{e} \rightarrow 2HO^-$$

The hydrogen and hydroxyl ions then combine in the electrolyte to produce water

$$H^+ + OH^- \rightarrow H_2O$$

The electrolyte is typically 40% KOH solution because of its high electrical conductivity and it is less corrosive tha acids. The above equations show that hydroxyl ions produced at one electrode are involved in the reaction at th other. Also electrons are absorbed from the oxygen electrode and released to the hydrogen electrode. Addition (the three forgoing reactions shows that when the cell is operating, the overall process is the chemical combination (hydrogen and oxygen (gases) to form water that is:

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$$

The oxygen and hydrogen are converted to water, which is the waste product of the cell. The reactants are store outside the cell (note difference from storage battery), and the electrodes and electrolyte are not consumed in th overall process.

K^+, of the electrolyte, providing an electrical double layer. Similarly, the loss of electrons from the oxyge electrode results in a layer of positive charges, which in turn attracts hydroxyl ions, OH^-, from the electrolyt These electrical double layer at the electrodes build up until the potentials are such that they inhibit only oth further reactions between the electrolyte and the fuel gases. This situation is illustrated in the figure showing that a open circuit voltage is developed between the electrodes. The magnitude of this emf is 1.23 volt at 1 atm and 25 ° C

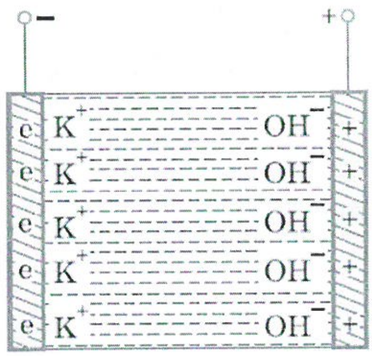


Fig. 10.2. Electrodes on open circuit.

If the circuit is closed (Fig. 10.3), the electrons can now leave the electrodes pass through the connecting circuit t the oxygen electrodes, and take part in the reaction of equation (10.2) above. This movement of electrons constitute a current passing through an external load. In this way useful electrical work is obtained directly from the chemic: process. Note that the electrons flow is from the hydrogen to the oxygen electrode.

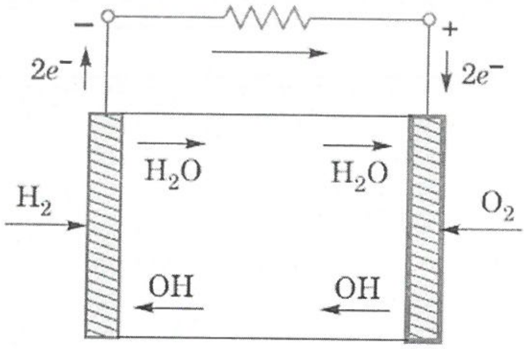


Fig. 10.3. Electrodes on closed circuit.

Hydrogen fuel cells (Hydrox) are of two types:

1. Low temperature cell. The electrolyte temperature is 90°C. It is some-times pressurized, but not by a gre: amount, usually say up to 4 atmospheres.
2. High pressure cell. Pressure is up to about 45 atmospheres and temperatures up to 300°C say.

A single "Hydrox" fuel cell can produce an e.m.f. of 1.23 volts at 1 atm and 25°C. By connecting a number of cell it is possible to create useful potential of 100 to 1000 volts and power levels of 1 kW to 100 MW nearly. Th current depends upon the physical size of the cell. The output of the fuel cell varies directly with the pressure, so a to increase the cell output, the gas pressure is raised. The optimum size of the cell at present is about 0.27 cu. m, pe kW.

The gases in the hydrogen oxygen cell must be free from carbon-dioxide, because this gas can combine with th potassium hydroxide electrolyte to form potassium carbonate. If this occurs, the electrical resistance of the cell increased and its output voltage is decreased. Consequently, when air is used to supply the required oxygen, carbo dioxide must first be removed by scrubbing with an alkaline medium (i.e., lime). Fuel cells are particularly suite for low voltage and high current applications. Hydrogen-oxygen fuel cells have been proposed for propulsion o electric vehicles, with the hydrogen provided by a metal hydride. However this use is limited by the heavy weight o the hydride and the cost of the relatively pure hydrogen required. It appears that for the present, at least the use o hydrogen oxygen cells.

10a. b) **Advantages and Disadvantages of Fuel Cell**

Advantages.

(1) It has very high conversion efficiencies as high as 70 per cent have been observed, since it is a direct conversio process and does not involve a thermal process. In the conventional thermal process for generating electricity, he: energy produced by combustion of the fuel is converted partially into mechanical energy in a steam turbine and the into electricity by means of a generator. The efficiency of a heat engine is limited by the operating temperature and in the large modern steam-electric plants above 40 per cent of the heat energy of the fuel is converted int electrical energy. Fuel cells, on the other hand, are not heat engines and are not subjected to their temperatu limitations.

(2) Fuel cells can be installed near the use point, thus reducing electrical transmission requirements an accompanying losses. Consequently considerably higher efficiencies are possible.

(3) They have few mechanical components; hence, they operate fairly quietly and require little attention and les maintenance.

(4) Atmospheric pollution is small if the primary energy source is hydrogen, the only waste product is water; if th source is a hydrocarbon, carbon dioxide is also produced, Nitrogen oxides, such as accompany combustion of foss fuels in the air, are not formed in the fuel cell. Some heat is generated by a fuel cell, but it can be dissipated to th atmosphere or possibles used locally.

(5) There is no requirement for large volumes of cooling water such as are necessary to condense exhaust syste from a turbine in conventional power plant.

(6) As fuel cells do not make noise, they can be readily accepted in residential areas.

(7) The fuel cell takes little time to go into operation.

(8) The space requirement for fuel cell power plant is consider ably less as compared to conventional power plants.

Disadvantages The main disadvantages of fuel cells are their high initial costs and low service life.

11. a) Hydrogen Storage

In an energy system there is a need to be able to store energy somewhere between the production point and th utilization point. The need for storage is due to the almost inevitable mismatch between the optimum productio rate of energy and the fluctuations in demand for energy by the users.

In the electric energy system storage, presents considerable difficulty because electricity itself is not readil storable. In contrast to the electrical energy system, both the gas energy and the oil energy systems are endowe with the capability store very large quantities of energy. The location of energy storage systems is very important. a large storage system can be installed very close to customer, the load factor on the transmission systems automatically raised, and therefore the transmission cost becomes lower.

There are five principle methods that have been considered for hydrogen storage, these are:

(1) Compressed gas storage.

(2) Liquid storage (cryogenic storage in vacuum insulated or superinsulated storage tank).

(3) Line pack system (allowing the pressure in the transmission or distribution system to vary).

(4) Underground storage (in depleted oil and gas fields or in aquifer systems).

(5) Storage as metal hydrides.

1. Compressed Gas Storage. Hydrogen is conveniently stored for many applications in high pressure cylinder This method of storage is rather expensive and very bulky because very large quantities of steel are needed t contain quite small amounts of hydrogen. In the conventional industrial hydrogen system, com-pressed gas is use to supply relatively small amounts of hydrogen, but when hydrogen is considered as a fuel, it is soon realized th tank storage of hydrogen is not really a practical proposition.

2. Liquid Storage. On a small scale or moderate scale, hydrogen is frequently stored under high pressure in stron steel cylinders, as stated above; this type of storage would be too costly for a large scale applications. A mo practical approach is to store the hydrogen as liquid at a low temperature, (i.e., cryogenic storage). For example, th liquid hydrogen fuel used as rocket propellant in the space program is stored in large tanks. Very large facilities fo hydrogen liquifaction have been designed and built, and large storage tanks have also been constructed. One majo difference exists between handling liquid natural gas and liquid hydrogen the storage temperature. Liquid hydroge boils at - 253°C and therefore must be maintained at or below this temperature in storage unless pressure build u can be tolerated.

(3) Line Packing. The use of line pack storage in the natural gas industry provides a relatively small-capacit storage system, but one with a very fast response time that can take care of minute by minute or hour by hou variations in demand. A hydrogen transmission and distribution system running on hydrogen would have a simila capability although the capacity would be reduced by 3 because of the reduced heating value of hydrogen, compare with natural gas. a factor of about

(4) Underground Storage. The cheapest way to store large amounts of hydrogen for subsequent distribution woul probably be in underground facilities similar to those used for natural gas; these facilities would include depleted o and gas reservoirs and aquifers. More expensive alternatives would be caverns produced by conventional mining (by dissolving out salt with water. Since hydrogen gas tends to escape readily through a porous material, som geologic formations that may be suitable for storing natural gas may not be suitable for hydrogen.

(5) Metal Hydrides (Storage in chemically bound form). Considerable interest has been shown recently in th possibility of storage of hydrogen in the form of a metal hydride. A number of metals and alloys form soli compounds, called metal hydrides, by direct reaction with hydrogen gas. When the hydride is heated, the hydroge is released and the original metal (or alloy) is recovered for further use. Thus, metal hydrides provide a possib means for hydrogen storage.

Applications

Hydrogen gas can be utilised:

(i) For residential uses (ii) For industrial uses

(iii) For as an alternative transport fuel

(iv) For as an alternative fuel for aircraft

(v) For electric power generation (utilities).

(i) Residential uses. Electricity for lighting and for operating domestic appliances (e.g., refrigerators) could b generated by means of fuel cells, with hydrogen gas at one electrode and air at the other.

Hydrogen can be used in domestic cooking. The burners of domestic appliances (e.g., stoves) would have to b modified if hydrogen were to replace natural gas. In the first place, since the heating value per unit volume (

modified if hydrogen were to replace natural gas. In the first place, since the heating value per unit volume (hydrogen gas is less than that of natural gas, a larger volume would have to reach the burners to achieve the sam heating effect.

(iii) Road vehicles. The use of hydrogen fuel in internal combustion engines for automobiles, buses, trucks, an farm machinery has attracted interest as a means of conserving petroleum products and of reducing atmospheri pollution. Because of the fuel is a gas, the conventional carburetor of a spark-ignition engine, in which liqui gasoline is vapourized in air, must be modified for use with hydrogen. The methods of using hydrogen as a fuel i CI engines are as follows:

(i) A mixture of fuel gas and air, with an approximately constant fuel to air ratio, is introduced into the cylind intake manifold. The engine power (i.e., vehicle speed) is controlled by varying the quantity of mixture entering th cylinder by means of a throttle value.

(ii) The hydrogen gas under pressure is injected through a valve directly into the engine cylinder, and the air admitted through another intake valve.

11, **b) Principle of MHD Power Generation**: The principle of MHD generation is simply that discovered by Farada when an electric conductor moves across a magnetic field, a voltage is induced in it which produces an electri current. This is the principle of the conventional generator also, where the conductors consist of copper strips. I MHD generator, the solid conductors are replaced by a gaseous conductor; an ionized gas. If such a gas is passed a high velocity through a powerful magnetic field, a current is generated and can extracted by placing electrodes in suitable position in the stream. This arrangement as illustrated in Fig. (12.1) provides d.c. power directly.

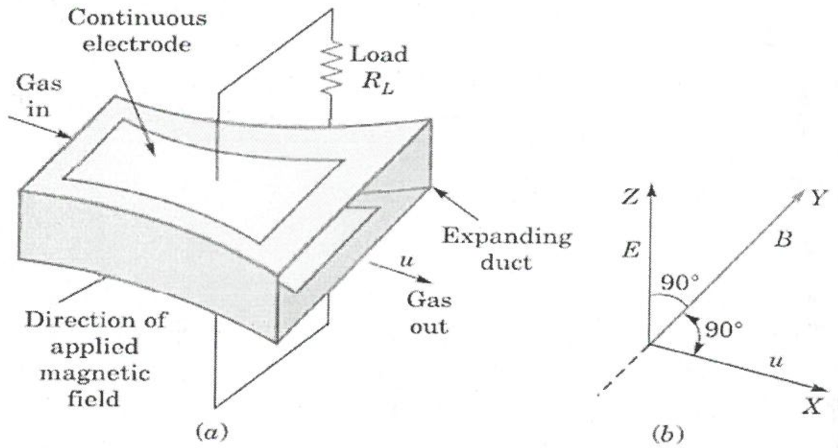


Fig. 12.1. Principle of MHD Power Generation.

The principle can be explained as follows. An electric conductor moving through a magnetic field experiences retarding force as well as an induced electric field and current. This effect is a result of Faraday's law (electromagnetic induction. The induced emf is given by

$$E_{ind} = \vec{u} \times \vec{B} \qquad .(12.1)$$

where, u is the velocity of the conductor and B is the magnetic, field intensity as shown in Fig. 12.1 (b). Th induced current density is

$$\vec{J}_{ind} = \sigma \vec{E}_{ind}$$

Where σ is electric conductivity. The retarding force on the conductor is the Lorentz force given by

$$\vec{F}_{ind} = \vec{J}_{ind} X \vec{B}$$

From an energy point of view, the movement of the force through a displacement (mechanical work) is converted t electrical work (current flow against potential difference) by means of the electromagnetic induction principle. Th is a work energy conversion and is not limited by the Carnot principle, of course, electromagnetic induction form the basis of operation for conventional electric generators.

magnetic field direction, an electromotive force (or electric voltage) is induced in the direction at right angles t both flow and field directions, as depicted in figure. This is the basic principle of MHD conversion (refer Fig. 12.2 A schematic of MHD generator is shown in Fig. 12.3. The conducting flow fluid is forced between the plates with kinetic energy and pressure differential sufficient to overcome the magnetic induction force F_{ind}. The end vie

Ionization is produced either by thermal means i.e., by an elevated temperature or by seeding with substance lik caesium or potassium vapours which ionize at relatively low temperatures. The atoms of the seed element split o electrons. The presence of the negatively charged electrons makes the carrier gas an electrical conductor. The oth way is to incorporate a liquid metal into a flowing carrier gas. Since the metal is a good electrical conductor, the ga metal mixture can be used as the working fluid in an MHD generator.
NOTE:MHD generator may also be considered.