

1. THERMOELECTRIC

1. Introduction • Thermoelectricity refers to a class of phenomena in which a temperature difference creates an electric potential or an electric potential creates a temperature difference. • Thermoelectric power generator is a device that converts the heat energy into electrical energy based on the principles of Seebeck effect • The pioneer in thermoelectric was a German scientist Thomas Johann Seebeck (1770-1831) • Later, In 1834, French scientist, Peltier and in 1851, Thomson (later Lord Kelvin) described the thermal effects on conductors
2. . Seebeck, Peltier and Thomson effect Seebeck effect When the junctions of two different metals are maintained at different temperature, the emf is produced in the circuit. This is known as Seebeck effect. The conductor 1 is maintained at $T+\Delta T$ temperature The conductor 2 is maintained at temperature 'T'. Since the junctions are maintained at different temperature, the emf 'U' flows across the circuit.
3. . Peltier effect Whenever current passes through the circuit of two dissimilar conductors, depending on the current direction, either heat is absorbed or released at the junction of the two conductors. This is known as Peltier effect. absorbed released
4. . Thomson effect Heat is absorbed or produced when current flows in material with a certain temperature gradient. The heat is proportional to both the electric current and the temperature gradient. This is known as Thomson effect. 3. Thermoelectric effect The thermoelectric effect, is the direct conversion of heat differentials to electric voltage and vice versa
5. Thermoelectric materials • The good thermoelectric materials should possess 1. Large Seebeck coefficients 2. High electrical conductivity 3. Low thermal conductivity • The example for thermoelectric materials • • • • BismuthTelluride (Bi_2Te_3), Lead Telluride (PbTe), SiliconGermanium (SiGe), Bismuth-Antimony (Bi-Sb)
6. . Principle, construction and working of Thermoelectric power generator Thermoelectric power generator based on the principle of Seebeck effect that when the junctions of two different metals are maintained at different temperature, the emf is produced in the circuit
Heat input Hot junction P-type N-type Cold junction Heat ejection Power output

7. • In order to select materials and design a thermoelectric generator, one needs to start with a general understanding of the thermoelectric effects. • In a thermoelectric material there are free carriers which carry both charge and heat. • Perhaps the simplest example is a gas of charged particles. • If a gas is placed in a box within a temperature gradient, where one side is cold and the other is hot, the gas molecules at the hot end will move faster than those at the cold end. • The faster hot molecules will diffuse further than the cold molecules and so there will be a net build up of molecules (higher density) at the cold end. • The density gradient will cause the molecules to diffuse back to the hot end.
8. • In the steady state, the effect of the density gradient will exactly counteract the effect of the temperature gradient so there is no net flow of molecules. • If the molecules are charged, the buildup of charge at the cold end will also produce a repulsive electrostatic force (and therefore electric potential) to push the charges back to the hot end. Diagram shows The charge buildup at cold side
9. • The electric potential produced by a temperature difference is known as the Seebeck effect and the proportionality constant is called the Seebeck coefficient. • If the free charges are positive (the material is p-type), positive charge will build up on the cold which will have a positive potential. • Similarly, negative free charges (n-type material) will produce a negative potential at the cold end.
10. . Construction Thermoelectric power generation (TEG) devices typically use special semiconductor materials, which are optimized for the Seebeck effect. The simplest thermoelectric power generator consists of a thermocouple, comprising a p-type and n-type material connected electrically in series and thermally in parallel. Heat is applied into one side of the couple and rejected from the opposite side. An electrical current is produced, proportional to the temperature gradient between the hot and cold junctions.
11. Therefore, for any TEPG, there are four basic component required such as • • • • Heat source (fuel) P and N type semiconductor stack (TE module) Heat sink (cold side) Electrical load (output voltage)
12. • The figure shows the construction of thermoelectric power generator. • There is a burner in which the propane fuel is used as heating source in one side. • The exhaust is used to transmit a burnt fuel. • On the other side, a cold junction is kept. • The thermoelectric module (TE) (consist of number of P- type and N-type semiconductor pellets connected

in series or parallel depending on the served load)) is kept in between the hot and cold junction. • The electrical out (load) is taken from the TE module.

13. Working When the two sides of semiconductor are maintained with different temperature, the emf is flows across the output circuit Cold side N-type Hot side Heat flow V Electron flow

14. • As the heat moves from hot side to cold side, the carrier moves in the semiconductor materials and the potential deference is created. charge hence • The electrons are the charge carriers in the case of Ntype semiconductor and Hole are in P-type semiconductors. • In a stack, number of semiconductors is connected. P-type and • A single PN connection can produce a Seebeck of 40 mV. N-type voltage • The heat source such as natural gas or propane are used for remote power generation

15. . Major Types available • Fossil fuel generators • Solar Source generators • Nuclear Fuel generators

. Advantages • Easy maintenance: They works electrically without any moving parts so they are virtually maintenance free. • Environment friendly: Thermoelectric generators produce no pollution. Therefore they are eco friendly generators. • Compact and less weight: The overall thermoelectric cooling system is much smaller and lighter than a comparable mechanical system. • High Reliability: Thermoelectric modules exhibit very high reliability due to their solid-state construction

• No noise: They can be used in any orientation and in zero gravity environments. Thus they are popular in many aerospace applications. • Convenient Power Supply: They operate directly from a DC power source.

Load : LED lighting TEG System

THERMIONIC GENERATOR

Introduction • Thermionic Power Converter is a static device that converts heat into electricity by boiling electrons from a hot emitter surface (approx 1800 K) across a small inter electrode gap (< 0.5 mm) to a cooler collector surface (approx 1000 K) • A Thermionic Generator consists of one or more of these converters coupled to give desired power output • Thermionic generators can be operated from any primary heat source. • For low power level (3 kW or less) solar energy can be used • For high power level (50 kW or more) nuclear heat source can be used

History • In 1883 Edison discovered release of electrons from a hot body • In 1904 Fleming invented thermionic diode rectifier • In 1915 Schlichter proposed thermionic conversion • After 1950 serious research on this began

Important aspects considered • The cathode must emit an abundant supply of electron • Evaporation of atoms from cathode should be negligible • Electronic space charge build-up in the interelectrode spacing must be eliminated

Classification Classification according to methods of neutralization space charge • Vacuum close-spaced • Cesium Gas Filled

Vacuum close-spaced convertor • Has been under extensive research since 1957 • Physical spacing of .0005 inch or less is maintained between anode and cathode • Will have engineering difficulty • Lifetime is 40 hours

Cesium Gas Filled • Cesium gas is filled between anode and cathode • Working efficiency is higher than former one • Lifetime is nearly 600 hours • Main problem is efficient sealing and corrosive nature of cesium

Advantages • • • • Rotating equipment is not employed Liquid-Vapour phase problems do not exist Separators for fluids are not required Frictional losses due to bearings not present

Disadvantage • Individual converters are low voltage, high current devices • A large number of converters must be sequentially arranged to obtain useful voltage • Power losses in converters can seriously cut useful power output

Comparison • Both thermionic and thermoelectric generators employ the electron gas as the working fluid • A thermionic generator based on the ballistic current flow which is highly efficient, and its theoretical efficiency is close to the Carnot efficiency • A thermoelectric generator, however, has poor efficiency due to the diffusive current flow • A thermionic generator usually requires a hightemperature heat source (e.g. 1500 K) to generate a practically useful current • A thermoelectric generator, however, can produce electrical power from low-quality heat energy sources