- Seebeck effect, Peltier effect and Thomson effect
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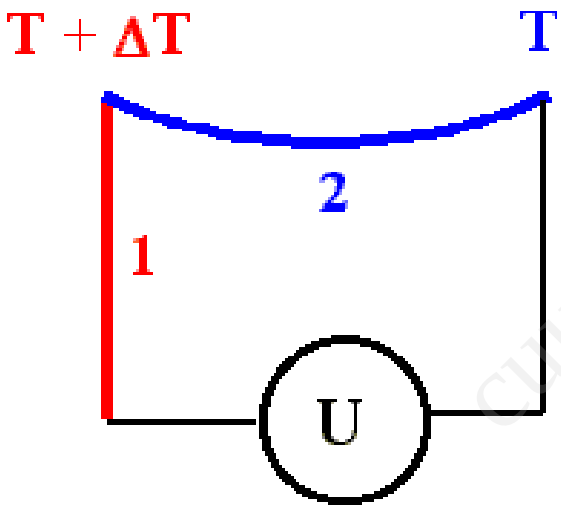
# Seebeck, Peltier and Thomson effect

*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*.

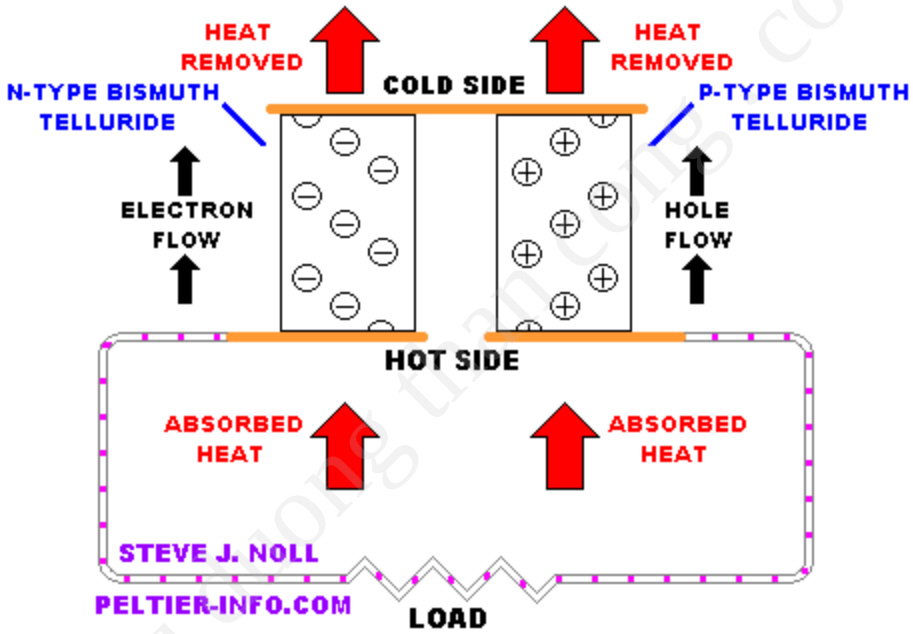



The conductor 1 is maintained at T+Δ***T*** temperature

The conductor 2 is maintained at temperature ‘T’.

Since the junctions are maintained at different temperature, the emf ‘U’ flows across the circuit.

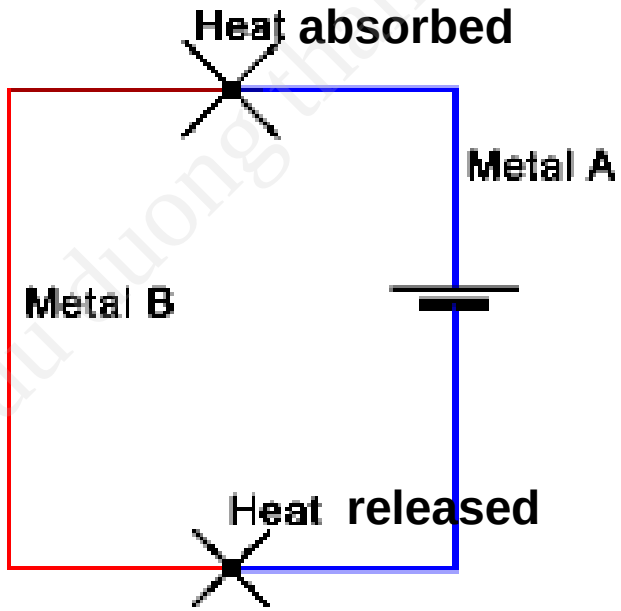
**ONE SEEBECK DEVICE "COUPLE" CONSISTS OF ONE N-TYPE AND ONE P-TYPE SEMICONDUCTOR PELLET**



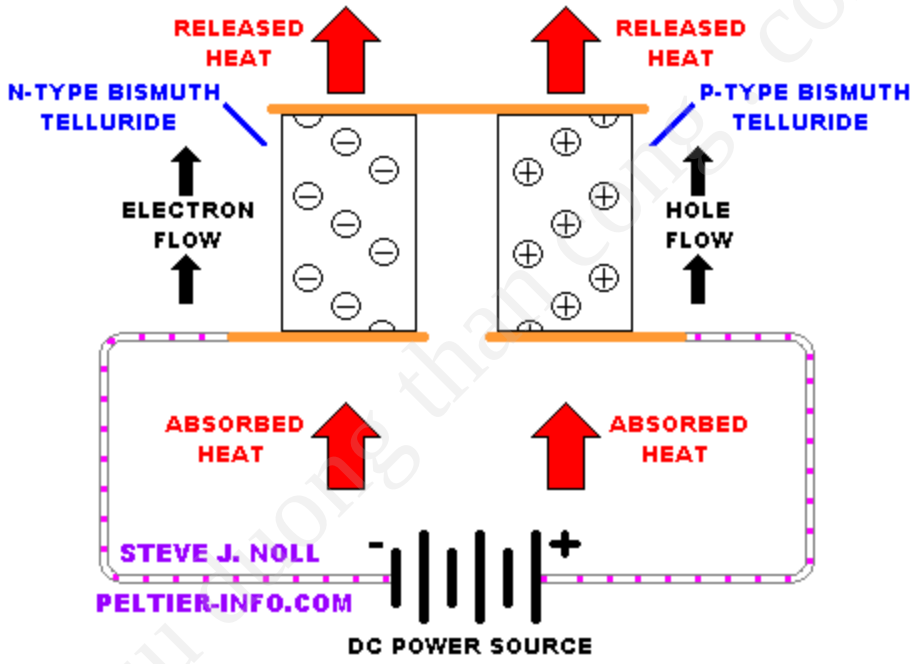

**THERE MUST BE A TEMPERATURE DIFFERENCE BETWEEN THE HOT AND COLD SIDES FOR POWER TO BE GENERATED**

## *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.



**ONE PELTIER DEVICE "COUPLE" CONSISTS OF ONE N-TYPE AND ONE P-TYPE SEMICONDUCTOR PELLET**




**THE CHARGE CARRIERS, NEGATIVE ELECTRONS AND POSITIVE HOLES, TRANSPORT THE HEAT.**

*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.

## Thermoelectric effect

The thermoelectric effect, is the direct conversion of heat differentials to electric voltage and vice versa..

# 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

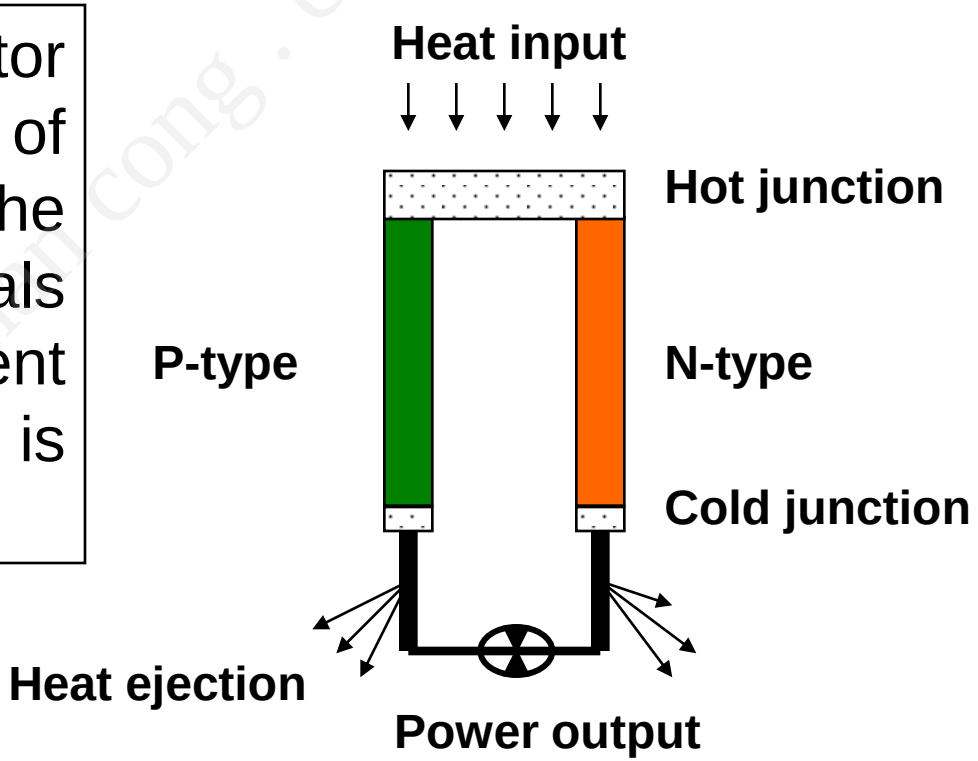
  - BismuthTelluride ($Bi_2Te_3$),
  - Lead Telluride (PbTe),
  - SiliconGermanium (SiGe),
  - Bismuth-Antimony (Bi-Sb)

# Figure of merit

A high electrical conductivity is necessary to minimize Joule heating and low thermal conductivity helps to retain heat at the junctions and maintain a large temperature gradient. These three properties were later put together and it is called figure-of-merit (Z).

# 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



- 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.

- 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.

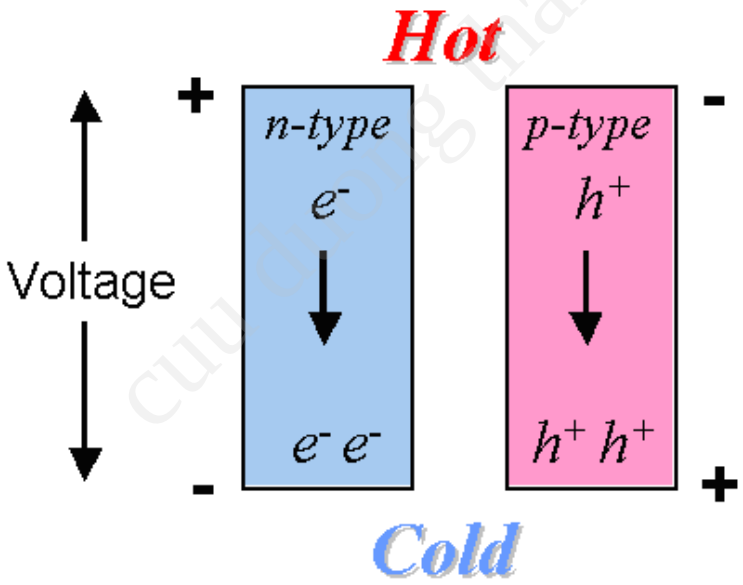



**Diagram shows**

**The charge buildup at cold side**

- 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.

## *Construction*

Thermoelectric power generation (TEG) devices typically use special semiconductor materials, which are optimized for the Seebeck effect.

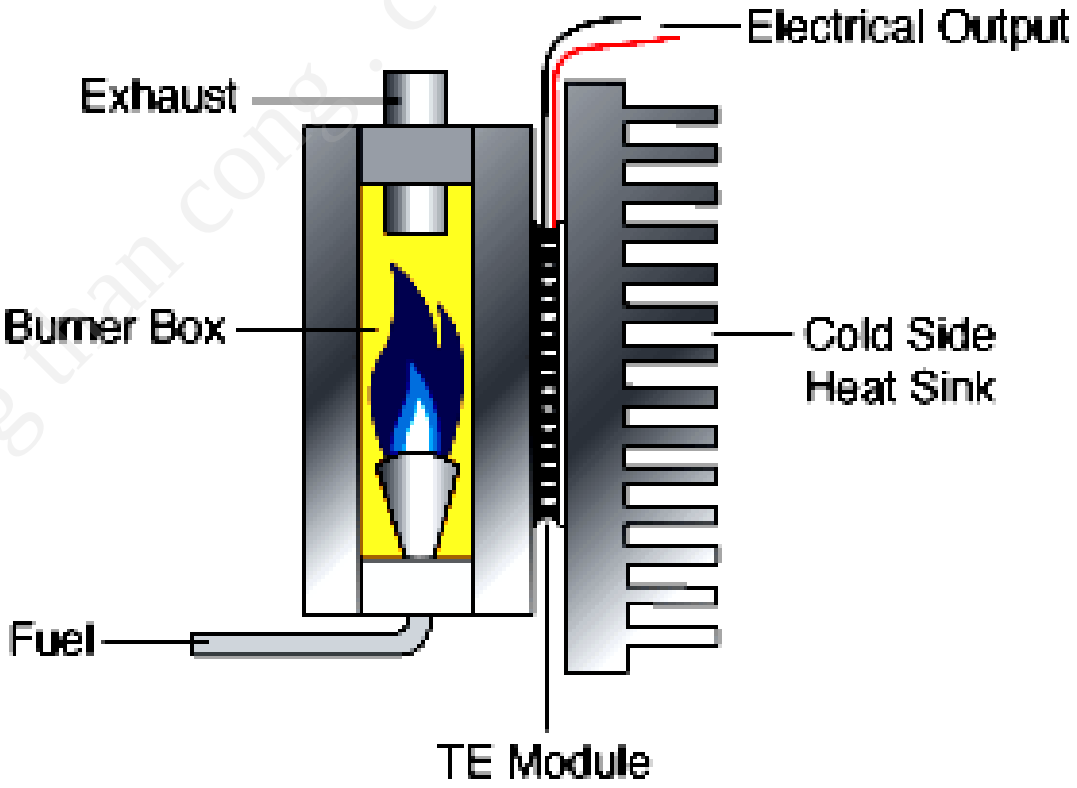
The simplest thermoelectric power generator consists of a thermocouple, comprising a p-type and n-type material connected electrically in series and thermally in parallel.

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.

Therefore, for any TEPG, there are four basic component required such as

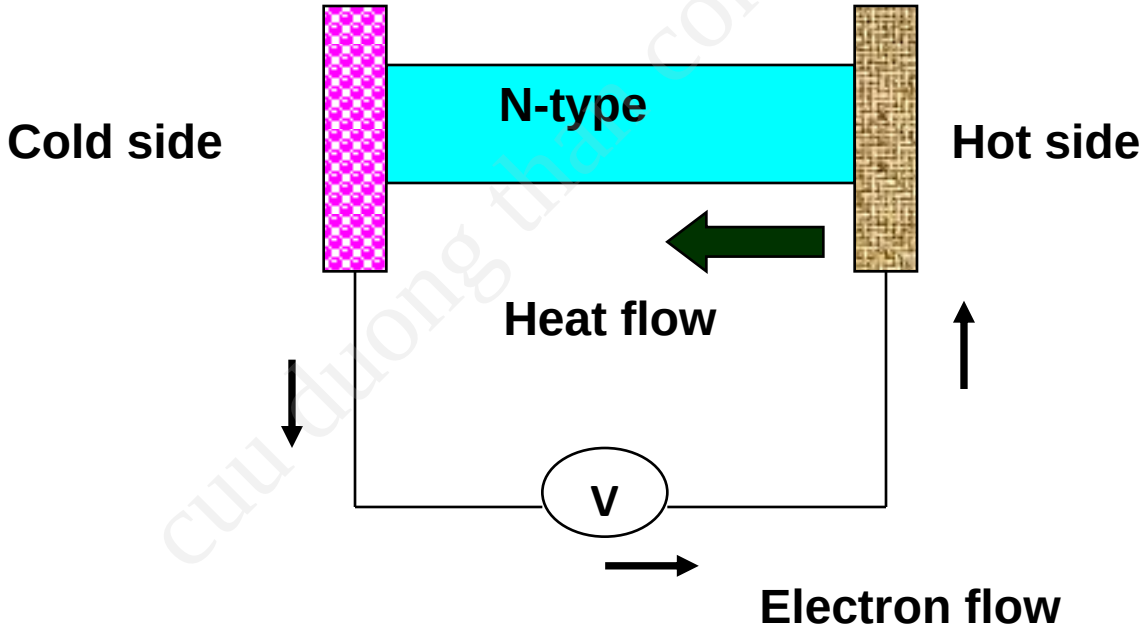
- Heat source (fuel)
- P and N type semiconductor stack (TE module)
- Heat sink (cold side)
- Electrical load (output voltage)



- 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.

## *Working*

When the two sides of semiconductor are maintained with different temperature, the emf is flows across the output circuit



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

# 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.