Department of Electrical Engineering
Assignment
Date: 23/06/2020

Course Details

Course Title: Direct Energy Conversions **Module:** ______
Instructor: Egnr shayan tariq **Total Marks:** 50

Student Details

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Note: Plagiarism of more than 20% will result in negative marking.
Similar answers of students will result in cancellation of the answer for all parties.

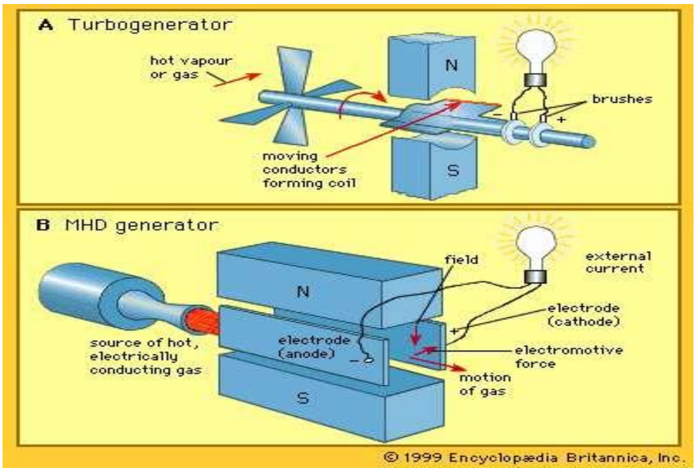
Q1.	(a)	Magneto hydrodynamics (MHD) is a direct energy conversion technique. What are the basic differences in working principle of this system as compared to conventional hydro power systems. How is the output power obtained from this system.	Marks 10
Q2.	(a)	Thermo-electric systems are emerging as a popular alternate to conventional thermal power systems. What are the main factors involved in the technology that determine the output power of thermos-electricgenerator. How can the maximum power be obtained from this system.	Marks 10
Q3.	(a)	The Thermionic generator has two main types (i) Vacuum Convertor and (ii) Cesium Gas Convertor. Explain in detail why which convertor is more efficient, has more life-time and is easier to construct/operate.	Marks 10
Q4	(a)	Thermo-electric and Thermionic are DEC techniques. What are the common principle in both systems. What are the main differences between both the systems. Explain in detail.	Marks 10
Q5	(a)	Thermo-Nuclear fusion has the potential to provide unlimited clean power. But the technology has not been mainstreamed due to technical difficulties. What are the main issues with the system. How can they be solved.	Marks 10

Q1 (a): **ID # 15628 MS (EE)**

Magneto hydro dynamic (MHD) power generation Process is basically based on the physics background of space Plasma. The basic principle is the Faradays Law of Electromagnetic induction. In this device plasma (Ionized gas) is the working fluid similar to the mechanism that happening in the magnetosphere of our earth's atmosphere. Except here the process is controlled and we increase the fluid density and pressure to get maximum efficiency in the generating power. For MHD, thermal energy is directly converted to electrical energy, hence know as direct energy conversion system. The MHD power plants can be classified as open and closed cycle based on the nature of processing of the working fluid. Magneto hydro dynamic power generator,any of a class of devices that generate electric power by means of the interaction of a moving fluid (usually an ionized gas or plasma) and a magnetic field. Magneto hydro dynamic (MHD) power plants offer the potential for large-scale electrical power generation with reduced impact on the environment. Since 1970, several countries have undertaken MHD research programs with a particular emphasis on the use of coal as a fuel. MHD generators are also attractive for the production of large electrical power pulses.

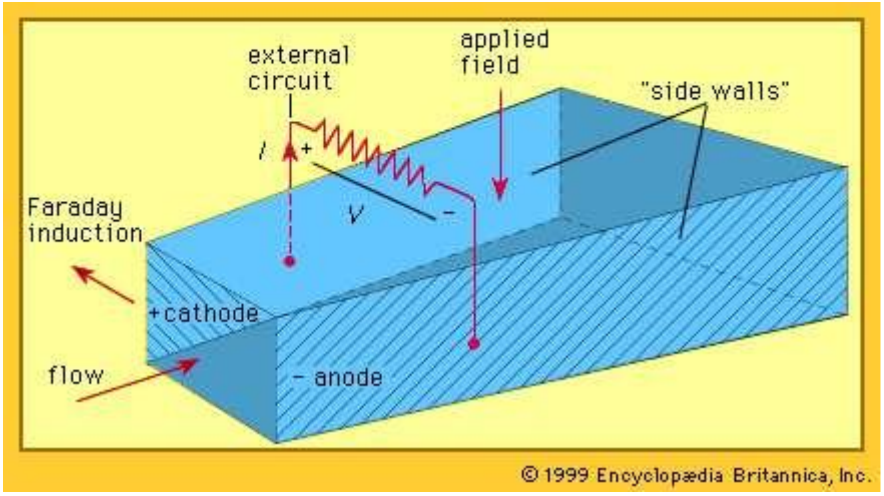
Working principle of HMD:

MHD power generation is elegantly simple. Typically, an electrically conducting gas is produced at high pressure by combustion of a fossil fuel. The gas is then directed through a magnetic field, resulting in an electromotive force within it in accordance with Faraday's law of induction (named for the 19th-century English physicist and chemist Michael Faraday). The MHD system constitutes a heat engine, involving an expansion of the gas from high to low pressure in a manner similar to that employed in a conventional gas turbo generator (*see* figure). In the turbo generator, the gas interacts with blade surfaces to drive the turbine and the attached electric generator. In the MHD system, the kinetic energy of the gas is converted directly to electric energy as it is allowed to expand.



Comparison of the operating principles of (A) a turbo generator and (B) an MHD generator.

the interaction of a plasma with a magnetic field could occur at much higher temperatures than were possible in a rotating mechanical turbine. The basic structure of an MHD generator is shown in the figure. In an MHD generator the hot gas is accelerated by a nozzle and injected into a channel. A powerful magnetic field is set up across the channel. In accordance with Faraday's law of induction, an electric field is established that acts in a direction perpendicular to both the gas flow and the magnetic field. The walls of the channel parallel to the magnetic field serve as electrodes and enable the generator to provide an electric current to an external circuit.



Simple MHD generator The load current is represented by *I* and the voltage by *V*.

How Conventional Hydropower Working:

Hydropower plants capture the energy of falling water to generate electricity. A turbine converts the kinetic energy of falling water into mechanical energy. Then a generator converts the mechanical energy from the turbine into electrical energy.

In order to generate electricity from the kinetic energy in moving water, the water has to move with sufficient speed and volume to spin a propeller-like device called a turbine, which in turn rotates a generator to generate electricity. Roughly speaking, one gallon of water per second falling one hundred feet can generate one kilowatt of electricity. To increase the volume of moving water, impoundments or dams are used to collect the water. An opening in the dam uses gravity to drop water down a pipe called a penstock. The moving water causes the turbine to spin, which causes magnets inside a generator to rotate and create electricity. There are a variety of types of turbines used at hydropower facilities, and their use depends on the amount of hydraulic head (vertical distance between the dam and the turbine) at the plant. The most common are Kaplan, Francis, and Pelton wheel designs. Some of these designs, called reaction and impulse wheels, use not just the kinetic force of the moving water but also the water pressure.

Output Power of the system:

The power output of an MHD generator for each cubic meter of its channel volume is proportional to the product of the gas conductivity, the square of the gas velocity, and the square of the strength of the magnetic field through which the gas passes. For MHD generators to operate competitively with good performance and reasonable physical dimensions, the electrical conductivity of the plasma must be in a temperature range above about 1,800 K (about 1,500 °C, or 2,800 °F). The turbine blades of a gas-turbine power system are unable to operate at such temperatures. An adequate value of electrical conductivity—10 to 50 Siemens per meter—can be achieved if an additive, typically about 1 percent by mass, is injected into the hot gas. This additive is a readily ionizable alkali material, such as cesium, potassium carbonate, or sodium, and is referred to as the “seed.” While cesium has the lowest ionizing potential (3.894 electron volts), potassium (4.341 electron volts) is less costly. Even though the amount of seed material is small, economic operation requires that a system be provided to recover as much of it as possible.

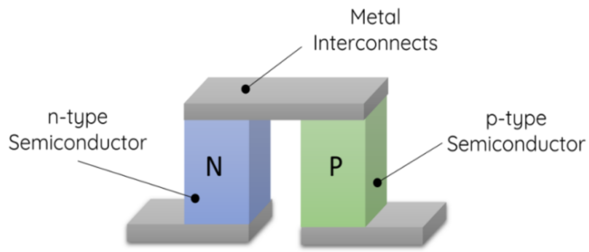
Q2 (a):

Thermo electricity:

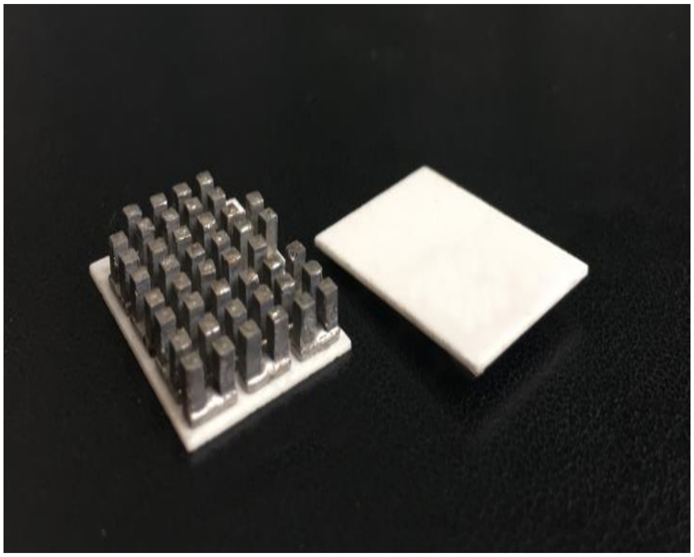
Electricity produced by the direct action of heat (as by the unequal heating of a circuit composed of two dissimilar metals) Thermoelectricity is a two-way process. It can refer either to the way a temperature difference between one side of a material and the other can produce electricity, or to the reverse: the way applying an electric current through a material can create a temperature difference between its two sides, which can be used to heat or cool things without combustion or moving parts. It is a field in which MIT has been doing pioneering work for decades.

Thermoelectric Generators Working:

Thermoelectric generators (TEG) are solid-state semiconductor devices that convert a temperature difference and heat flow into a useful DC power source. Thermoelectric generator semiconductor devices utilize the Seebeck effect to generate voltage. This generated voltage drives electrical current and produces useful power at a load. A thermoelectric generator is not the same as a thermoelectric cooler. (also know as TEC, Peltier module, cooling chips, solid-state cooling) A thermoelectric cooler works in reverse of a thermoelectric generator. When a voltage is applied to thermoelectric cooler, an electrical current is produced. This current induces the Peltier effect. With this effect, heat is moved from the cold side to the hot side. A thermoelectric cooler is also a solid-state semiconductor device. The components are the same as a thermoelectric generator but the design of the components in most cases differ. While thermoelectric generators are used to produce power, thermoelectric coolers are used for removing or adding heat. Thermoelectric cooling has many applications in cooling, heating, refrigeration, temperature control and thermal management. The focus of the rest this post is thermoelectric generators. The basic building block of a thermoelectric generator is a thermocouple. A thermocouple is made up of one p-type semiconductor and one n-type semiconductor. The semiconductors are connected by a metal strip that connects them electrically in series. The semiconductors are also known as thermo elements, dice or pellets.



Thermoelectric Generator Couple


Thermoelectric Generator (Pellets, Dice, Semiconductors, Thermo elements)

The See beck effect is a direct energy conversion of heat into a voltage potential. The See beck effect occurs due to the movement of charge carriers within the semiconductors. In doped n-type semiconductors, charge carriers are electrons and in doped p-type semiconductors, charge carriers are holes. Charge carriers diffuse away from the hot side of the semiconductor. This diffusion leads to a buildup of charge carriers at one end. This buildup of charge creates a voltage potential that is directly proportional to the temperature difference across the semiconductor.

Main Factor Involve:

1) EFFECTS OF TEMPERATURE DEPENDENCE OF THERMOELECTRIC PROPERTIES

The performance of the thermoelectric devices is influenced by the allocation of thermal conductance of heat exchangers between the hot and cold sides when the external heat transfer is considered. The power and efficiency will always improve with increase in temperature difference if the temperature dependence of thermoelectric properties is not considered. On the other hand the power improves very slowly whereas the efficiency decreases after its maximum with the increase of temperature difference, considering the influence of temperature dependence of thermoelectric properties. Effects of temperature dependence on power versus electrical current and Effects of temperature dependence on efficiency versus electrical current.

2) DESIGN CONSIDERATIONS FOR THERMOELECTRIC GENERATOR SYSTEM COMPONENTS:

Before starting the module selection process, the designer should be prepared to answer the following questions:

At what temperature your object is maintained?

How much heat is removed from heat source?

How much cooling effect is obtained from cooling Source?

How much space is available for the module and heat sink?

What power is available?

Does the temperature of the cooled object have to be controlled? If yes, to what precision?

What is the expected approximate temperature of the heat sink during operation?

Is it possible that the heat sink temperature will change significantly due to ambient fluctuations etc.?

3) Heat transfer law:

The external irreversibility is caused by the finite rate heat transfer between the thermoelectric generator and its heat reservoirs. When the heat transfer law is nonlinear then there are optimal working electrical currents and optimal ratio of thermal conductance allocations corresponding to the maximum power output and maximum efficiency. Since there are a variety of heat exchangers for thermoelectric device, the heat transfer laws are various and different from each other.

4) EFFECTS OF CONTACT RESISTANCE AND LEG LENGTH:

Good thermoelectric material properties are inevitable requirements for a thermoelectric module exhibiting high efficiency. And describe the impact of the module's contact resistance on the performance of thermoelectric generators. Even with very good thermoelectric material, the device performance can be rather poor, if the contact resistances of the module are too large. The merit *ZT* of a thermoelectric generator is a measure of the performance and is closely related to the efficiency of a module. It is strongly affected by the modules Resistance and is given by.

$$ZT = \frac{S^2 \sigma T}{\kappa}$$

5) **MATHEMATICAL MODELING:** The mathematical modeling must be in consideration which is main point and factor involved. The realized mathematical model of thermoelectrically cooling module is a method with which the user easily can calculate the base thermal physical parameters of TEM and for the semiconductors thermocouples, and in graphical way to report the absorbed thermal power.

6) THERMOELECTRIC GENERATOR ON SEEBACK EFFECTS:
The important design parameters for a power generator device are the efficiency and the power output. The efficiency is defined as the ratio of the electrical power output. The efficiency is defined as the ratio of the electrical power output Po to the thermal power input qh to the hot junction.

n = p0/qh

Efficiency increase: On the following basis efficiency will be increase.

1) Large seed back coefficient.

2) High electric conductivity.

3) Low thermal conductivity.

Q3: (a)

A thermionic generator (converter) converts heat energy directly to electrical energy by utilizing thermionic emission effect. All metals and some oxides have free electrons which are released on heating. In a thermionic converter, electrons act as the working fluid in place of a vapor or gas. In this device electrons are emitted from the surface of heated metal. The energy required to extract an electron from the metal is known as work function and expressed in electron volts. The work function depends upon the nature of metal and its surface condition.

Comparison between two main types:

Vacuum converters:

The available power and the efficiency of a thermionic converter can be severely limited by buildup of space charge between the electrodes. The vacuum type of thermionic converter uses a very small gap between its emitter and collector electrodes typically 0.025 to 0.038 mm (0.001 to 0.0015 inch) in order to minimize the effects of this electronic space charge. At a temperature of 1,100 K (about 800 °C, or 1,500 °F) the electric power converted is 0.1 to 1 watt per square centimeter of emitter surface. Converters with such small spacing's are difficult to manufacture, though. As a result, the vacuum converter has had only limited practical application. Its life time is 40 hrs. And will have engineering problem.

Cesium Gas-filled:

These devices are designed so that positively charged ions are continuously generated and mixed with negatively charged electrons in the space between the emitter and the collector to provide a plasma with a relatively neutral space charge. Because of this, a liberated electron encounters little electrostatic resistance force in passing from the emitter to the collector. Alkali metals are used to produce a readily ionizable vapor. Cesium is used in the most efficient converters because of its low ionization potential (3.89 electron volts). Potassium, rubidium, and various other elements may also be used. The **v**apors is normally on the order of 100 Pascal's. Contact ionization occurs when the ionization potential is less than the work function of the emitter material. Tungsten is a suitable emitter material because of its ability to operate at relatively high temperatures. Its life time is 600hrs.the main problem occur will sealing and corrosive nature of cesium but its working efficiency is higher than former one.

Which one is more Efficient:

A thermionic energy converter (TEC) is a device that harvests electrical power from heat and unlike thermoelectric converters requires a vacuum or low-pressure gas ambient to operate efficiently. In contrast to thermoelectric devices, TECs are normally operated at elevated temperatures well above red heat to realize large thermionic emission currents and can be considered as a heat engine whereby a large temperature difference between the cathode and cooled anode collector is required for optimum efficiency. In my point of view the best choice is cesium Gas filled because of it greater working efficiency and it has 600hr life time much more than others. it is easier and will have not engineering difficulty so in my point of view it will be the best choice and it construction and operation is much more easier. Fractional losses due to bearing not present in Converter and the rotating equipment is not employed.

Q4 (a):

When electrons sweep through a double-hetero junction structure, there exist thermionic

effects at the junctions and thermoelectric effects in the film. While both thermo electric and thermionic effects have been studied for refrigeration and power generation applications

Separately, their interplay in hetero structures is not understood. The process by which free electrons are emitted from the surface of a metal when external heat energy is applied is called thermionic emission.

Thermionic emission occurs, when large amount of external energy in the form of heat is supplied to the free electrons in the metals. When a metal is heated sufficiently, the thermal energy supplied to the free electrons causes the emission of electrons from the metal surface.

This occurs because the thermal energy given to the carrier overcomes the work_function of the material. At average room temperature, the energy possessed by free electrons in a metal is insufficient to initiate thermionic emission

A thermionic generator (converter) converts heat energy directly to electrical energy by utilizing thermionic emission effect. All metals and some oxides have free electrons which are released on heating. In a thermionic converter, electrons act as the working fluid in place of a vapors or gas. In this device electrons are emitted from the surface of heated metal. The energy required to extract an electron from the metal is known as work function and expressed in electron volts (eV). The work function depends upon the nature of metal and its surface condition.

Thermoelectricity means the direct conversion of heat into electric energy, or vice versa. The term is generally restricted to the irreversible conversion of electricity into heat described by the English physicist James P. Joule and to three reversible effects named for Seebeck, Peltier, and Thomson, their respective discoverers.

The similarities between both energies is both conver heat to electricity and both are working on heat thermo electric convert heat directly to electricity and thermionic when heat is applied to the system directly the in the external heat is applied the free electron is emitted. Boyh are working on the principle of heat energy.

Difference between both:

In thermionic free electrons are emitted from the surface of a metal when external heat energy is applied emission occurs in metals that are heated to a very high temperature when the large amount of external energy is applied. Thermoelectricity means the direct conversion of heat into electric energy direct conversion of temperature differences to electric voltage devices create a voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, heat is transferred from one side to the other, creating a temperature difference. So it works on the basis of potential difference.

Q5:

During the recent 400 years, the world population has grown more than ten-fold to the 6.5 billion people that today inhabit the Earth. Over the next 50 years the world's population is expected to grow from the present value to a level in the range 8–12 billion, and energy needs are expected to double or even triple during that period. Therefore, it is a major challenge to provide these people with clean and safe energy sources. At present, almost 80% of the energy production comes from fossil fuels and their burning generates huge amounts of carbon dioxide (CO2) which pollutes the environment, induces the greenhouse effects and extreme climate changes. Energy from the so-called renewable sources is very dilute and its power per unit of surface used is low, e.g., from solar energy – (5–50) W/m2, from hydro--energy about 11 W/m2, from on-shore and off-shore wind – (2–3) W/m2 , and from biomass – 0.5 W/m2 only. For a substantial contribution renewable power production plants depend on the size and localization of a country. Appropriate installations are very large and costly, e.g., to produce about 70 GW from photo-voltaic and on-shore wind installations. Hence, it seems that the only option for the future might be energy produced by thermonuclear reactors which might use nuclear fusion of heavy hydrogen isotopes, i.e. deuterium (D) and tritium (T). This opinion is shared by the Culham Centre for Fusion Energy. It should be noted that thermonuclear reactors will not produce any long-living radioactive wastes and they will not threaten any explosion, but there are many diffi cult technological issues to be solved before the first energetic fusion reactor is put into operation.

Why is fusion power so difficult?

One big reason is that it requires working with plasma, which is really tricky. Because plasmas aren't that common on Earth, scientists had very little experience with them until they started studying fusion.

1) **Plasma is difficult to hold:** The plasma used in fusion-energy research is hundreds of millions of degrees Fahrenheit. You can't hold it using a solid container, because the container would just melt. Instead, physicists have to corral it using electromagnetic fields or work with it so quickly (in less than a billionth of a second) that holding it isn't an issue.
2) **Plasma is difficult to compress:** If you don't compress plasma from all sides perfectly evenly, it will squish out wherever it can. Scientific American explained this well: "Imagine holding a large, squishy balloon. Now squeeze it down to as small as it will go. No matter how evenly you apply pressure, the balloon will always squirt out through a space between your fingers. The same problem applies to plasmas. Anytime scientists tried to clench them down into a tight enough ball to induce fusion, the plasma would find a way to squirt out the sides."
3) **Generation and containment of high-temperature plasma:**

As mentioned above, nuclear energy can be released not only by the fission of heavy nuclei, but also by the enrich atomic. In order to achieve positive energy balance in a thermonuclear reactor based on controlled fusion reactions, high-temperature plasma must have appropriate concentration and life-time. To produce and heat up plasma one can use different methods. The most simple is a powerful electrical discharge between electrodes placed inside a vacuum chamber and supplied form a high-voltage condenser bank.

4) **Technological requirements for thermonuclear reactors:**

The size of a thermonuclear reactor must be relatively large and its construction very complex. All the main structural components must be designed very carefully. The main technical problems connected with the design of a vacuum vessel and plasma facing compo-nents are very high thermal and corpuscular loads. It is estimated that the plasma facing components must withstand thermal loads.

5) Fusion fuel supplies:

In order to operate a thermonuclear reactor one must deliver appropriate amounts of deuterium and tritium, e.g., a large fusion power station generating 1500 MW of electricity will consume about 400 g of deuterium and about 600 g of tritium. Power deposited by fast fusion-produced neutrons in the neutron blanket can be extracted by means of an appropriate heat exchange circuit and delivered to conventional electrical generators. Hence, one can easily image a scheme of a future thermonuclear power station. Pure deuterium can be obtained from electrolysis of heavy water (D2O), which can relatively easily be separated from ordinary water, or from isotopic exchange in a hydrogen-sulphate gas. The separation of hydrogen isotopes can also be done by means of gas chrome.

6) Materials issue:

A very important issue is the behavior of first wall materials, which should have a high thermal conductivity, high resistance to thermal shocks, high stability under neutron irradiation, low chemical erosion, oxygen remnants gettering (if possible), low affinity to deuterium and tritium towards formation of volatile products, and a low sorption of hydrogen isotopes. Therefore, particular attention must be paid to the investigation of different constructional materials.

Problems solutions:

Thermonuclear fusion is a way of achieving nuclear fusion using extremely high temperatures. There are two types of thermonuclear fusion; controlled and uncontrolled.
Controlled thermonuclear fusion occurs in an environment where the energy produced can be harnessed for constructive purposes, while uncontrolled thermonuclear fusion occurs in thermonuclear weapons, such as the hydrogen bomb, or H-bomb.
The key to achieving thermonuclear fusion is confinement; due to the high temperatures, the plasma cannot be in contact with any solid material, and so must be confined in a vacuum
There are three types of confinement used for achieving thermonuclear fusion; gravitational confinement, magnetic confinement, and inertial confinement.
Gravitational confinement is only found in stars, as the mass needed to satisfy the Lawson criterion for fusion is so great, that only stars, the smallest of which are red dwarfs, or, if of sufficient mass, brown dwarfs, which can fuse deuterium and lithium together, can achieve this method of confinement. Magnetic confinement is used when the electrically charged particles, such as fuel ions, follow the magnetic field lines, and so the fusion fuel can be contained using a strong magnetic field. Inertial confinement requires a rapid pulse of energy to be applied to a large pellet of fusion fuel, which causes it to implode and heat to a high pressure and temperature. to solve these proble is not easy but we can mange these or we can reduce it as we know that plasma is not easily find on earth we have to mange it ist for our requirements.
Generation and containment of high-temperature plasma is required while Technological requirements for thermonuclear reactors must take in consideration we have to design it with all

aspects and considerations. the we have to make easier the fusion fuel supplies. It must be near and easily accessible. Materials issue must be solved particular attention must be paid to the investigation of different constructional materials.

‘‘END’’