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LUKHDHIRJI ENGINEERING COLLEGE

MORBI

A Project Report
On

NUCLEAR REACTOR

Under subject of
DESIGN ENGINEERING – 2A
B.E. Semester – V

(Chemical Branch)

Submitted by

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Academic Year: - 2015-2016

CERTIFICATE

CERTIFICATE

Date: __________

This is to certify that **Karan Gupta, Mehul Patel, Devarshi Tadvi, Rajesh Parmar, Sanjay Vasava** of B.E. Semester V (Chemical Engineering) has completed their Design Engineering-2A work titled "Nuclear Reactor" satisfactorily in partial fulfillment for requirement of Design Engineering-2A course, Gujarat Technical University, Ahmedabad, in the academic year 2015-2016.

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Chapter 1: Introduction

A nuclear reactor is a device to initiate and control a sustained nuclear chain reaction. The most common use of nuclear reactors is for the generation of electric energy and for the propulsion of ships.

The nuclear reactor is the heart of the plant. In its central part, the reactor core's heat is generated by controlled nuclear fission. With this heat, a coolant is heated as it is pumped through the reactor and thereby removes the energy from the reactor. Heat from nuclear fission is used to raise steam, which runs through turbines, which in turn powers either ship's propellers or electrical generators.

Since nuclear fission creates radioactivity, the reactor core is surrounded by a protective shield. This containment absorbs radiation and prevents radioactive material from being released into the environment. In addition, many reactors are equipped with a dome of concrete to protect the reactor against both internal casualties and external impacts.

Nuclear reactors

A nuclear reactor is a device to initiate and control a sustained nuclear chain reaction. The most common use of nuclear reactors is for the generation of electric energy and for the propulsion of ships.

Steam turbine

The purpose of the steam turbine is to convert the heat contained in steam into mechanical energy. The engine house with the steam turbine is usually structurally separated from the main reactor building. It is so aligned to prevent debris from the destruction of a turbine in operation from flying towards the reactor.

In the case of a pressurized water reactor, the steam turbine is separated from the nuclear system. To detect a leak in the steam generator and thus the passage of radioactive water at an early stage, an activity meter is mounted to track the outlet steam of the steam generator. In contrast, boiling water reactors pass radioactive water through the steam turbine, so the turbine is kept as part of the control area of the nuclear power plant.

Generator

The generator converts kinetic energy supplied by the turbine into electrical energy. Low-pole AC synchronous generators of high rated power are used.

Cooling system

A cooling system removes heat from the reactor core and transports it to another area of the plant, where the thermal energy can be harnessed to produce electricity or to do other useful work. Typically the hot coolant is used as a heat source for a boiler, and the pressurized steam from that one or more steam turbine driven electrical generators.

Safety valves

In the event of an emergency, safety valves can be used to prevent pipes from bursting or the reactor from exploding. The valves are designed so that they can derive all of the supplied flow rates with little increase in pressure. In the case of the BWR, the steam is directed into the suppression chamber and condenses there. The chambers on a heat exchanger are connected to the intermediate cooling circuit.

Feed-water pump

The water level in the steam generator and nuclear reactor is controlled using the feedwater system. The feed-water pump has the task of taking the water from the condensate system, increasing the pressure and forcing it into either the steam generators (in the case of a pressurized water reactor) or directly into the reactor (for boiling water reactors).

EMPATHY MAPPING CANVAS:

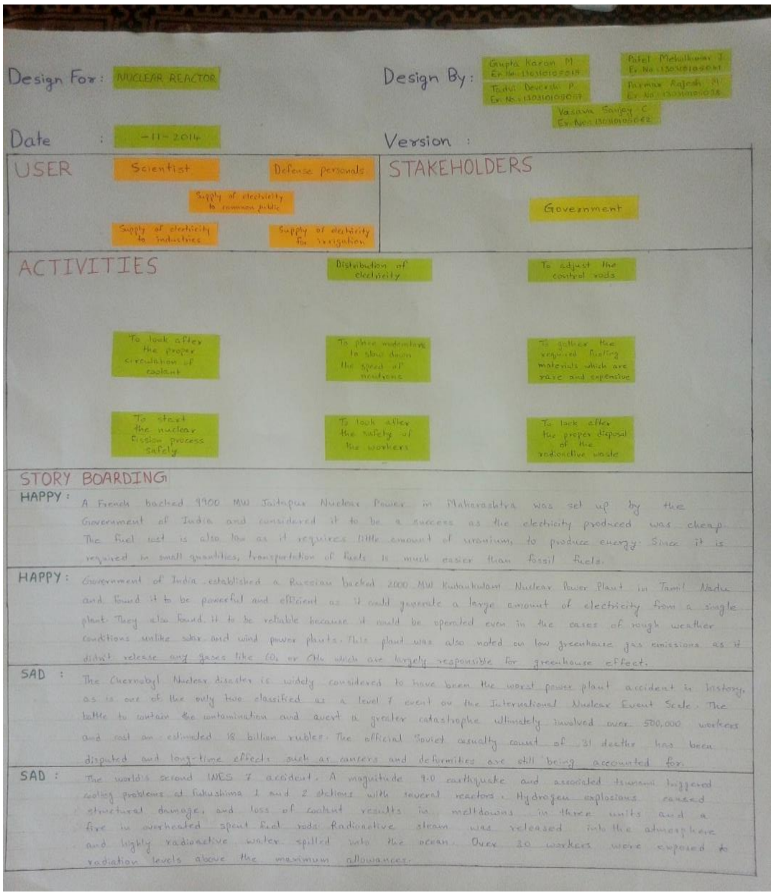


Fig. 1.1: Empathy mapping canvas

IDEATION CANVAS:

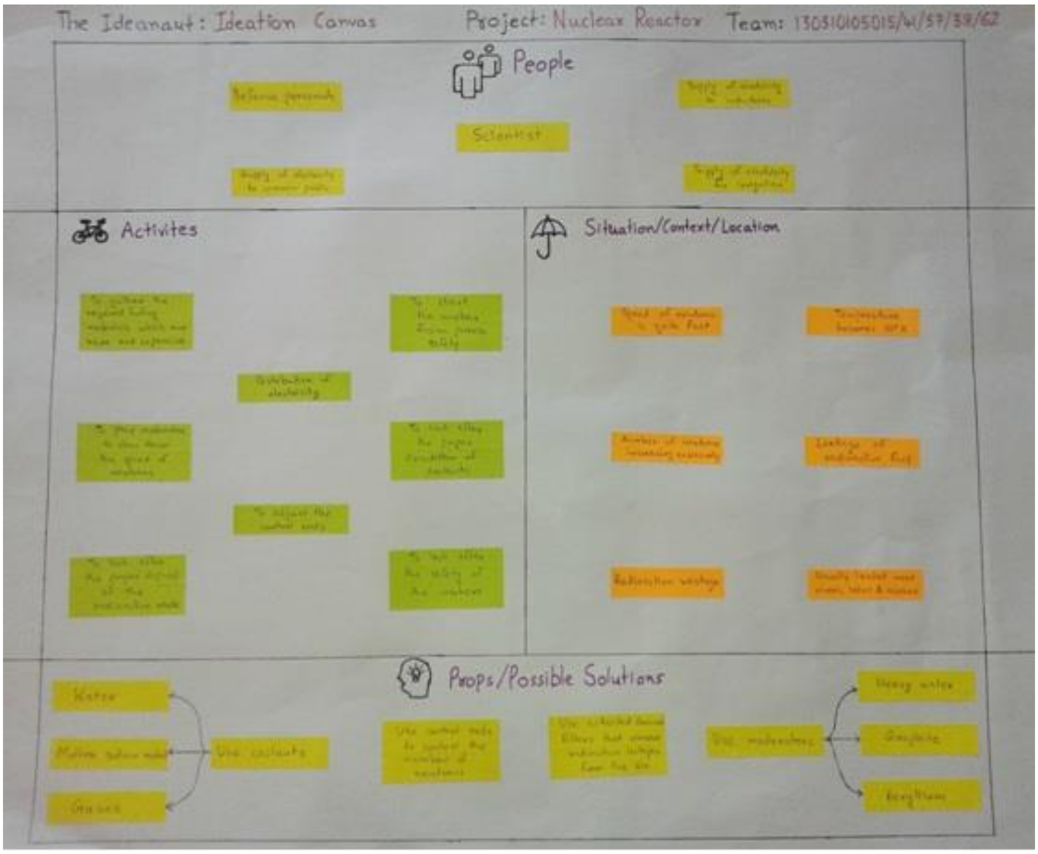


Fig. 1.2: Ideation canvas

PRODUCT DEVELOPMENT CANVAS:

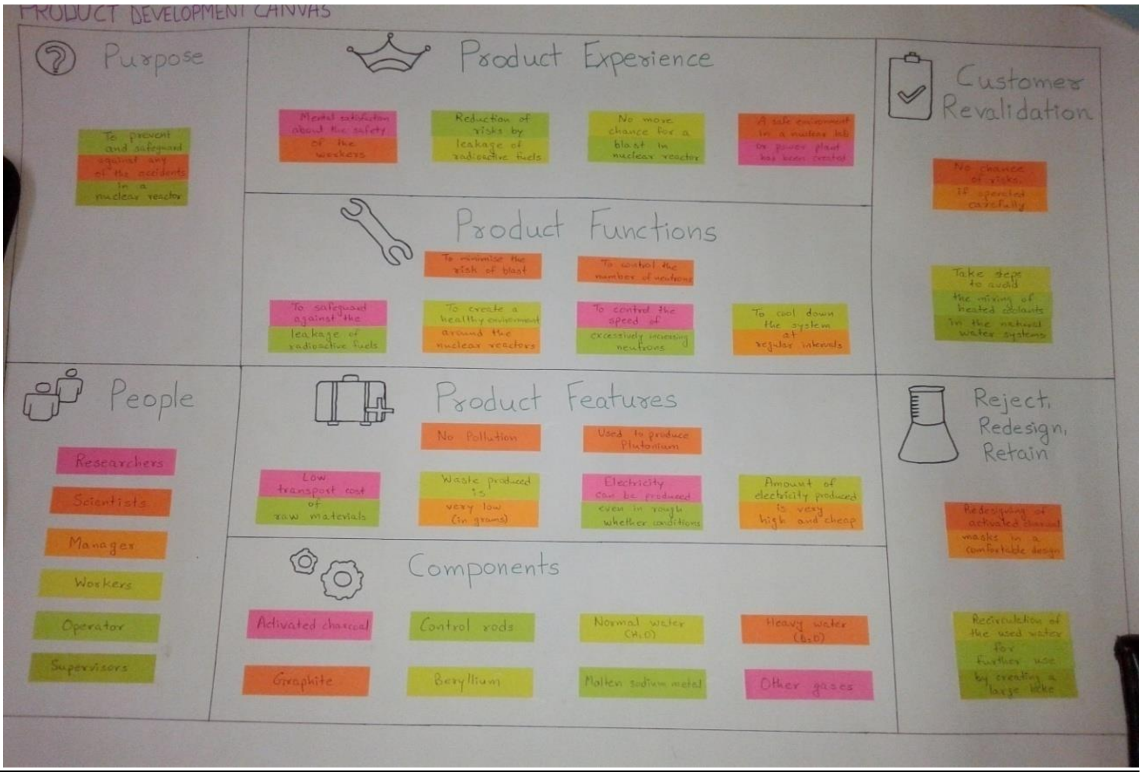


Fig. 1.3: Product development canvas

➢ **Activities:-**

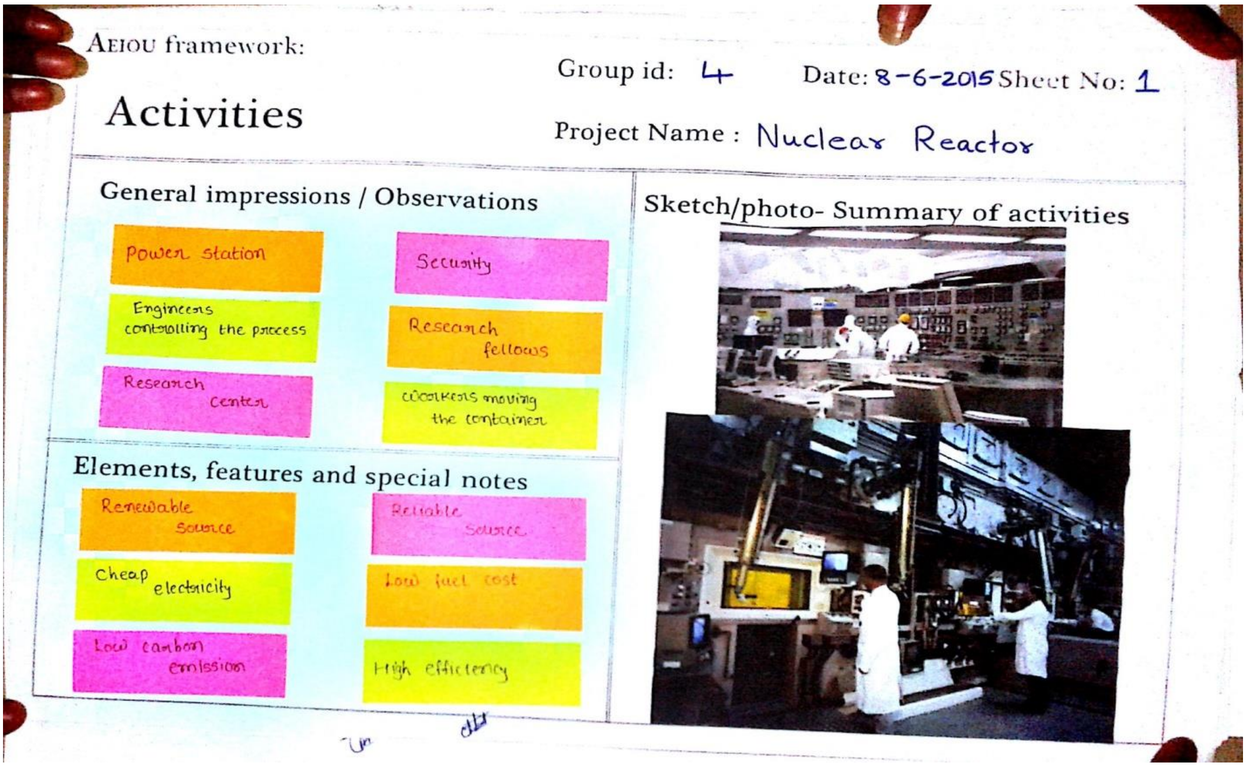


Fig. 1.4: Activity canvas

➢ Environment:-

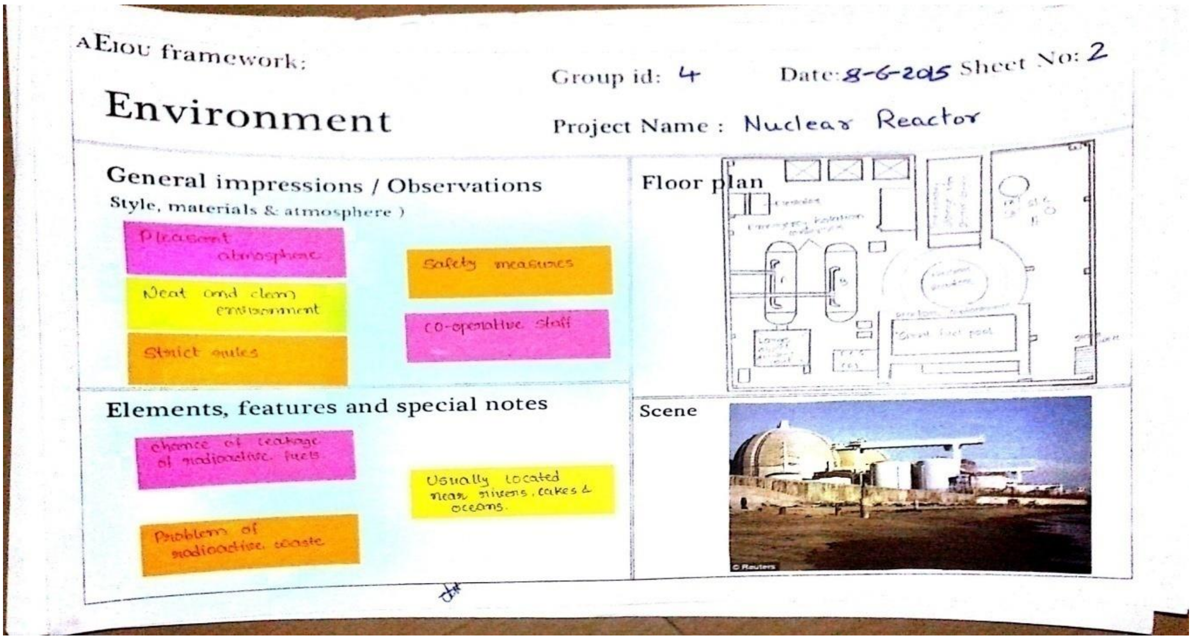


Fig. 1.5: Environment canvas

➢ Interaction:-

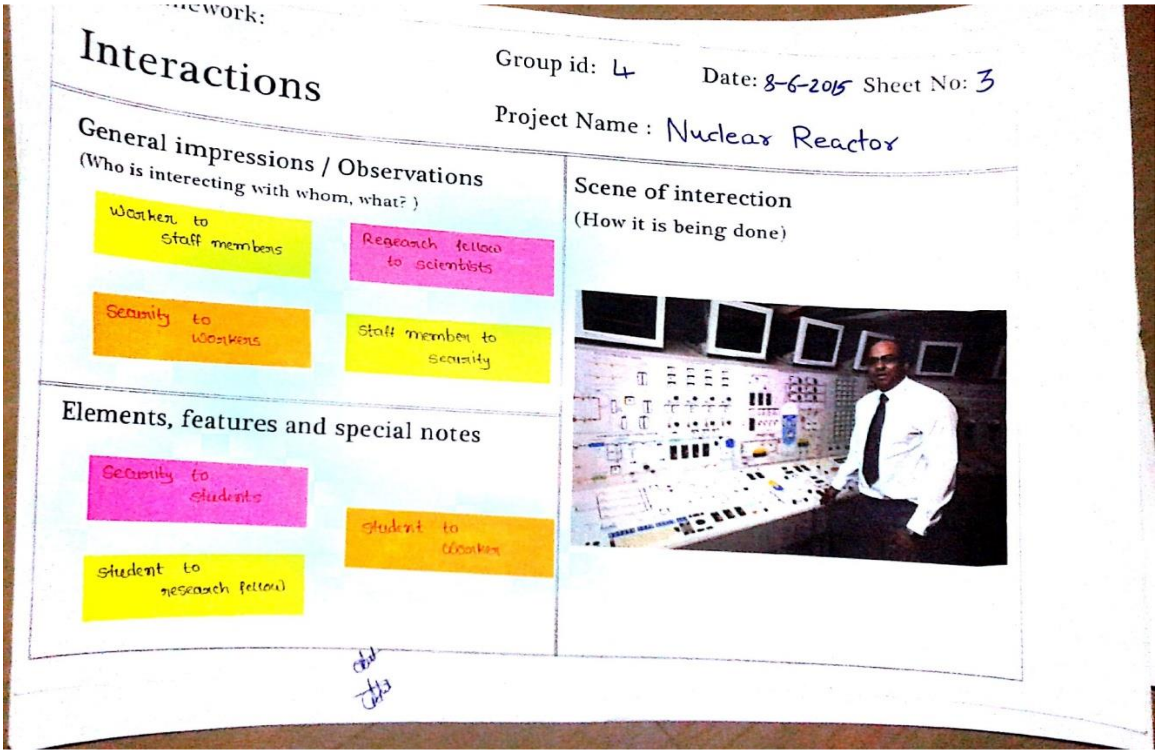


Fig. 1.6: Interaction canvas

➢ **Objects:-**

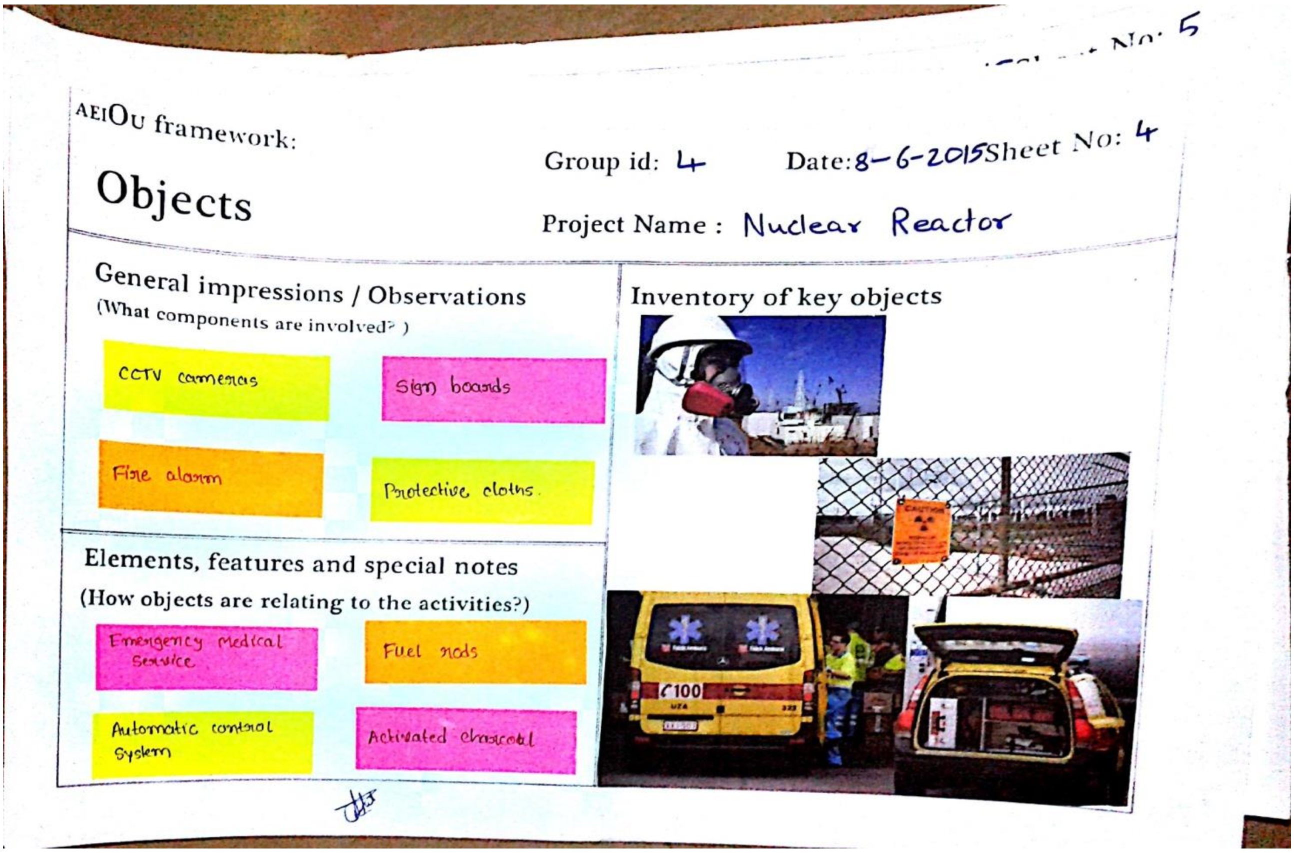


Fig. 1.7: Objects canvas

➢ **User:-**

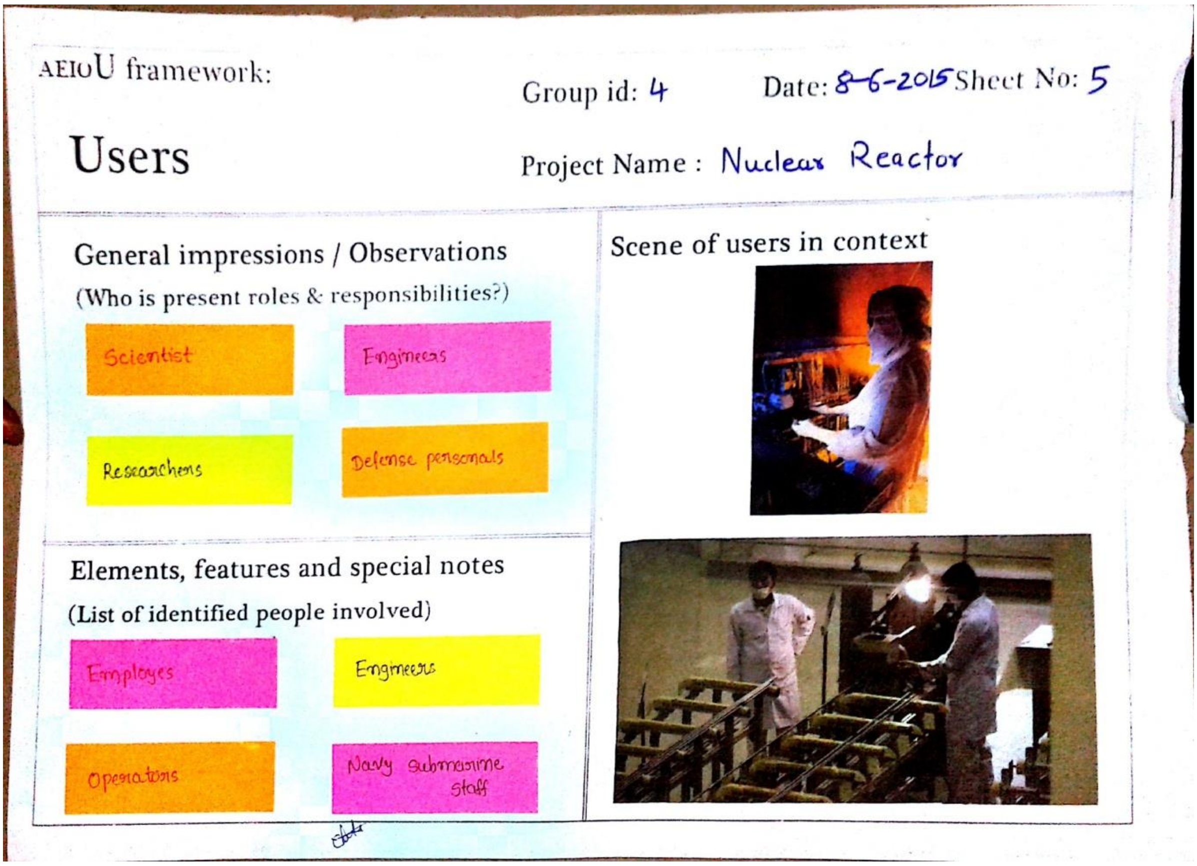


Fig. 1.8: Users canvas

➤ Learning Needs Matrix:-

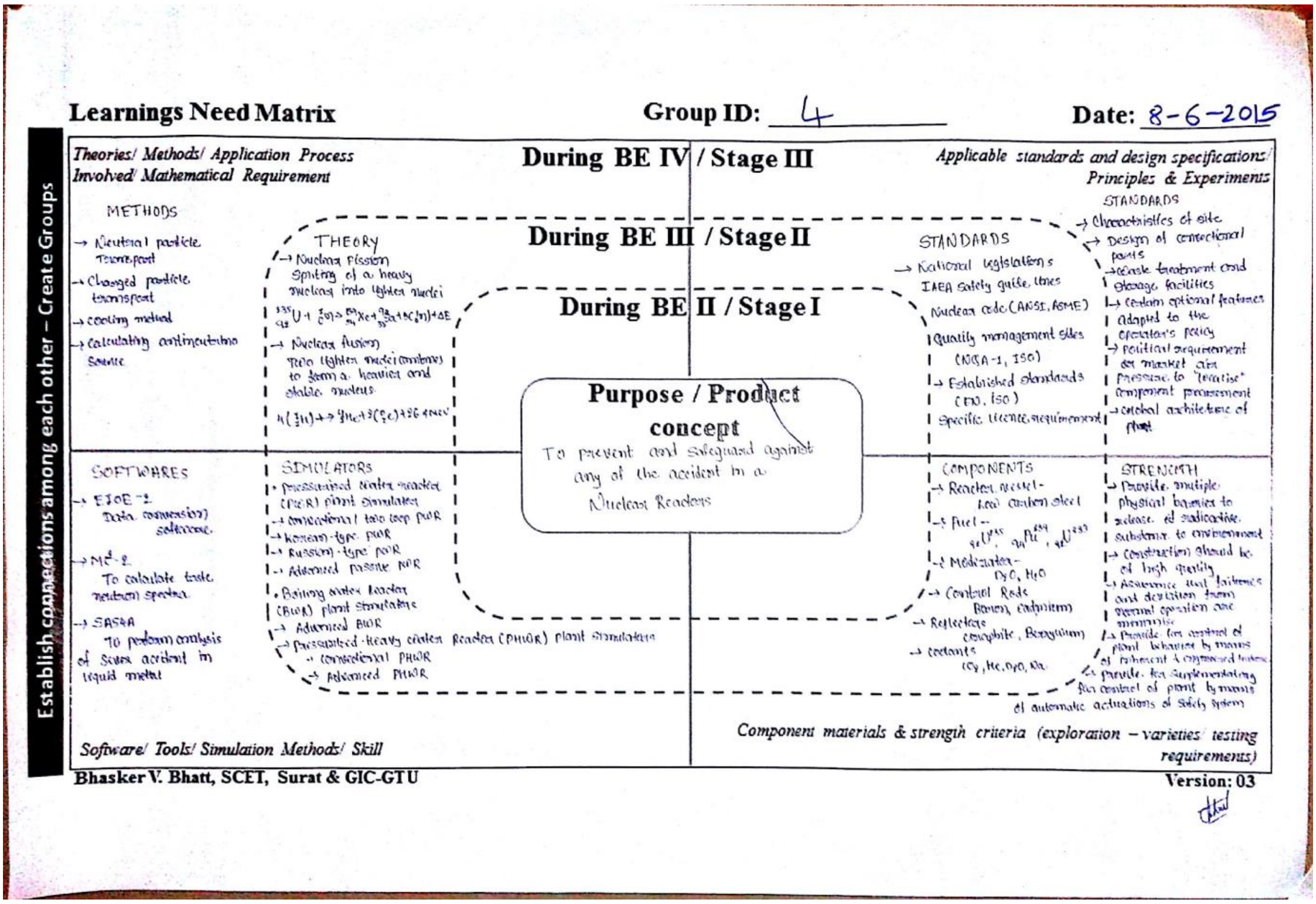


Fig. 1.9: Matrix canvas

Chapter 2: Literature / Secondary Research:-

The neutron was discovered in 1932. The concept of a nuclear chain reaction brought about by nuclear reactions mediated by neutrons was first realized shortly thereafter, by Hungarian scientist Leo Szilard, in 1933. He filed a patent for his idea of a simple nuclear reactor the following year while working at the Admiralty in London.However, Szilard's idea did not incorporate the idea of nuclear fission as a neutron source, since that process was not yet discovered. Szilard's ideas for nuclear reactors using neutron-mediated nuclear chain reactions in light elements proved unworkable.

Inspiration for a new type of reactor using uranium came from the discovery by Lies Meitner, Fritz Stresemann and Otto Hahn in 1938 that bombardment of uranium with neutrons (provided by an alpha-on-beryllium fusion reaction, a "neutron howitzer") produced a barium residue, which they reasoned was created by the fissioning of the uranium nuclei. Subsequent studies in early 1939 (one of them by Szilard and Fermi) revealed that several neutrons were also released during the fissioning, making available the opportunity for the nuclear chain reaction that Szilard had envisioned six years previously.

Pressurized water reactors (PWR)

These reactors use a pressure vessel to contain the nuclear fuel, control rods, moderator, and coolant. They are cooled and moderated by high-pressure liquid water. The hot radioactive water that leaves the pressure vessel is looped through a steam generator, which in turn heats a secondary (non-radioactive) loop of water to steam that can run turbines. They are the majority of current reactors. This is a thermal neutron reactor design, the newest of which are the VVER-1200, Advanced Pressurized Water Reactor and the European Pressurized Reactor. United States Naval reactors are of this type.

Boiling water reactors (BWR)

A BWR is like a PWR without the steam generator. A boiling water reactor is cooled and moderated by water like a PWR, but at a lower pressure, which allows the water to boil inside the pressure vessel producing the steam that runs the turbines. Unlike a PWR, there is no primary and secondary loop. The thermal efficiency of these reactors can be higher, and they can be simpler, and even potentially more stable and safe. This is a thermal neutron reactor design, the newest of which are the Advanced Boiling Water Reactor and the Economic Simplified Boiling Water Reactor.

Pressurized Heavy Water Reactor (PHWR)

A Canadian design (known as CANDU), these reactors are heavy-water-cooled and -moderated pressurized-water reactors. Instead of using a single large pressure vessel as in a PWR, the fuel is contained in hundreds of pressure tubes. These reactors are fuelled with natural uranium and are thermal neutron reactor designs. PHWRs can be refuelled while at full power, which makes them very efficient in their use of uranium (it allows for precise flux control in the core). CANDU PHWRs have been built in Canada, Argentina, China, India, Pakistan, Romania, and South Korea. India also operates a number of PHWRs, often termed 'CANDU-derivatives', built after the Government of Canada halted nuclear dealings with India following the 1974 Smiling Buddha nuclear weapon test

Chapter 3: Design considerations for detail design part:-

(3.1) Design for Performance, Safety and Reliability: -

(3.1.1) Safety: -

(3.1.1.1) Reactor protection system (RPS)

A reactor protection system is designed to immediately terminate the nuclear reaction. By breaking the chain reaction, the source of heat is eliminated. Other systems can then be used to remove decay heat from the core. All nuclear plants have some form of reactor protection system.

(3.1.1.2.) Controlling neutrons

Control rods are a series of rods that can be quickly inserted into the reactor core to absorb neutrons and rapidly terminate the nuclear reaction. They are typically composed of actinides, lanthanides, transition metals, and boron, in various alloys with structural backing such as steel. In addition to being neutron absorbents, the alloys used also have to have at least a low coefficient of thermal expansion so that they do not jam under high temperatures, and they have to be self-lubricating metal on metal, because at the temperatures experienced by nuclear reactor cores oil lubrication would foul too quickly.

(3.1.1.3) Low pressure coolant injection system

Low pressure coolant system consists of a pump or pumps that inject coolant into the reactor vessel once it has been depressurized. In some nuclear power plants, Low pressure coolant injection system is a mode of operation of a residual heat removal system. Low pressure coolant system is generally not a stand-alone system.

(3.1.1.4) Reactor vessel

The reactor vessel is the first layer of shielding around the nuclear fuel and usually is designed to trap most of the radiation released during a nuclear reaction. The reactor vessel is also designed to withstand high pressures.

(3.1.2) Reliability:

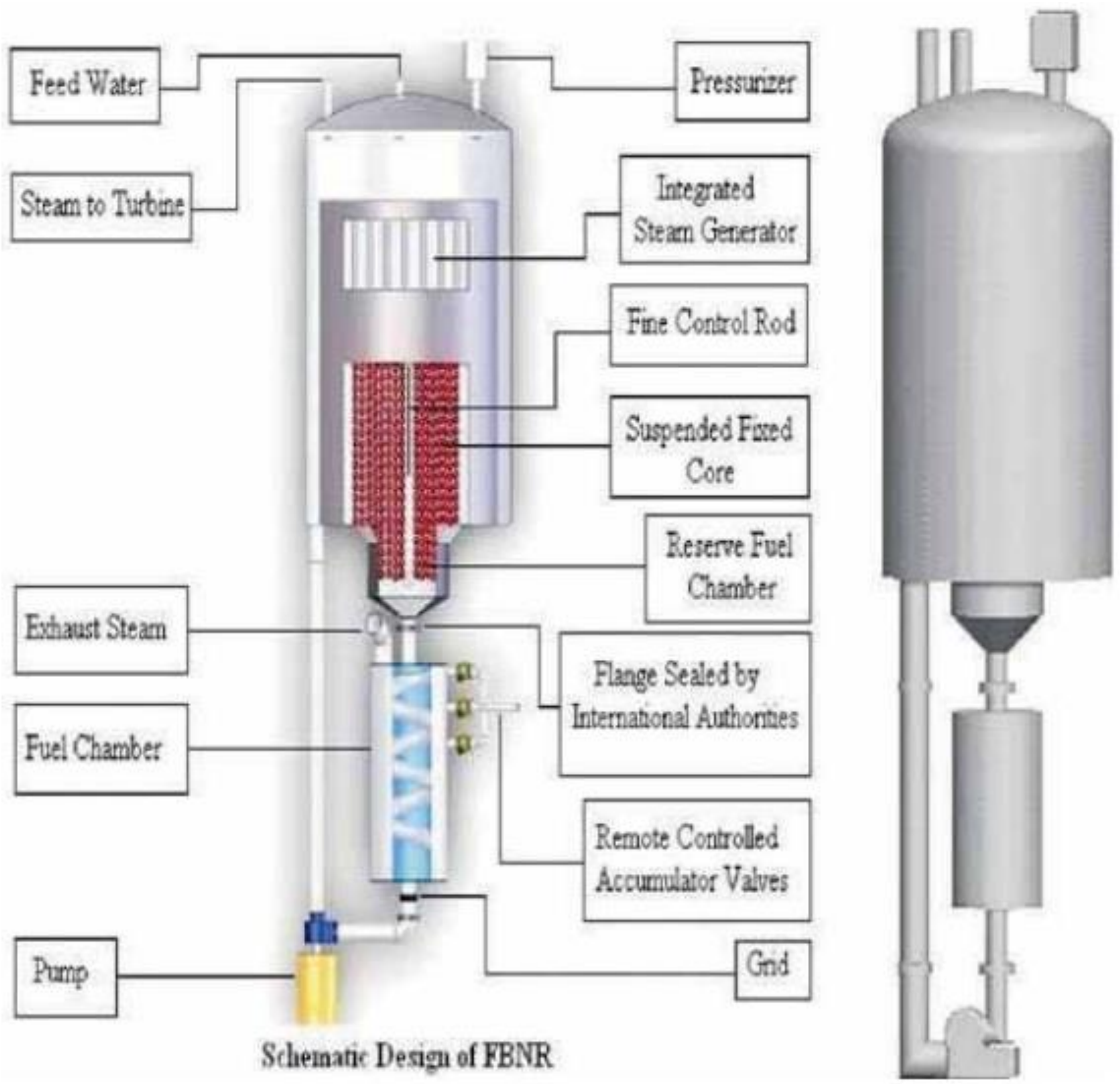
Nuclear power is the most efficient and reliable source of large-scale, around-the-clock electricity. High reliability and dependability mean that electricity is available on the grid whenever needed, all the time. This is particularly important during periods of extreme heat or cold. Another part of reliability is the energy-intensive nature of uranium fuel. A single uranium pellet, slightly larger than a pencil eraser, contains the same energy as a ton of coal, three barrels of oil or 17,000 cubic feet of natural gas. Each uranium fuel pellet provides heat for up to five years to make steam for power generation, making uranium an important part of base load fuel diversity that ensures grid stability. Nuclear plants are built to run all the time and provide full power when it is most needed. A third of a reactor's fuel is replaced every 18-24 months during short, scheduled spring and fall refuelling outages. This means America's nuclear energy plants can supply large amounts of predictable, reliable electricity through virtually every period of extreme heat and cold.

(3.2) Design for Ergonomics and Aesthetics: -

Ergonomics are not playing the role they deserve in the design of process control systems making them less controllable than they could be if human factors were adequately incorporated. The use of ergonomics approach in the design of process control systems throughout the industry presents many opportunities for improvements with regard to system effectiveness, efficiency, reliability and safety. Nachreiner et al. (2006) used the following quote "The control room displays did not help the operators to understand what was happening" from a major accident in a chemical process plant as an indication that, at least, not all process control graphic interfaces represent the state of the art in human factors/ergonomics design approach. Nachreimer et al also claimed that, especially in the design of VDU-based control system (graphic screens) human factors or ergonomics principles already known must be applied according to the existing legislation in European countries. In this research, we focused on the design and layout of the graphics on the simulators screens of a nuclear power plant simulator, and the integration of the alarm system into the control/display environment. Nuclear power plant (NPP) control room operators observe and manipulate a complex system comprising about ten thousand parameters. In conventional control rooms, operators walk along a large control panel, taking readings from gauges and manipulating knobs and levers. Modern control rooms have been upgraded with visual display units (VDUs). Unlike the old analog control rooms, in the new "advanced" interfaces all operators can access almost all the information about the plant from his/her workplace (Vicente et al, 1997). Digitization of previous analog human-system interfaces imposes new coordination demands on operational teams (e.g. the need for communication to construct situation awareness) leading to new situations of human-human and human–system interaction. In order to run such systems effectively, efficiently, and safely, (often conflicting goals) much research has been developed taking into account human performance, technological possibilities, types/levels of automation in a system, design of human–machine interfaces, etc. (see Parasuraman et al., 2000; Sheridan, 2002; Woods,1996; Nachreiner et al., 2006). The overall research aim is to investigate how advanced (digital) interfaces should be evaluated and designed in order to be used in the modernization of the analog instrumentation and human/system interface (HSI) systems. The research presented in this article focused on the development of operator support systems during emergency situations. In particular, we focused on crucial safety problems related to the design and layout of the graphics on the screen, and the layout and in formativeness of the alarm system.

(3.3) Design for Manufacturability and Assembly (DFMA): -

Quality management in LWR (Light Water Reactor) fuel manufacturing for the use in German reactors is based on international guidelines and national/local authority requirements defined in operational licenses. The quality management is twofold and comprises a quality assurance system and the check of manufacturing documents including witnessing of fabrication processes and inspections. Utility and authority appointed technical expert witness manufacturing and take part in inspections performed by the manufacturer where the scope is strictly defined and does not provide possibilities of flexible responses to manufacturing occurrences. For future developments in quality management HEW supports strengthening the ideas of quality planning. Analysis of all factors influencing fuel reliability shall be performed prior to manufacturing. This will increase the efforts in reviewing of drawings and specifications. Included here shall be a review of processes that will be used in manufacturing. The qualification and robustness of processes shall be demonstrated with special qualification programs and analysis of manufacturing statistics. Instead of product/project related inspections the use of all manufacturing data will provide a complete picture of the manufacturing quality. By applying statistical methods it will be possible to identify trends in manufacturing before deviations occur. So the basic driving force to implement statistical process control for the utilities is the wish to get comprehensive information of delivered quality, whereas for manufacturers it might be to increase production yields and thus to lower costs. The introduction and full use of statistical process control requires open information about manufacturing processes and inspection results by the manufacturers. This might include data judged to be economically sensitive. It also requires changes in attitude at the utilities and appointed experts. HEW has started to review and change internal guidelines to allow implementation of modern quality management instruments. Nuclear fuel plays an essential role in ensuring the competitiveness of nuclear energy and its acceptance by the public. The economic and market situation is not favorable at present for nuclear fuel designers and suppliers. The reduction in fuel prices (mainly to compete with fossil fuels) and in the number of fuel assemblies to be delivered to customers (mainly due to burn up increase) has been offset by the rising number of safety and other requirements, e.g. the choice of fuel and structural materials and the qualification of equipment. In this respect, higher burn up and thermal rates, longer fuel cycles and the use of MOX fuels are the real means to improve the economics of the nuclear fuel cycle as a whole. Therefore, utilities and fuel vendors have recently initiated new R&D programmers aimed at improving fuel quality, design and materials to produce robust and reliable fuel for safe and reliable reactor operation more demanding conditions.



(3.1)Fig. Design for Manufacturability Assembly (DFMA):

(3.4) Design for Cost, Environment:-

(3.4.1) Cost

If we want to reduce the climate impact of electric power generation in the United States, there are less costly and risky ways to do it than expanding nuclear power. A 2011 UCS analysis of new nuclear projects in Florida and Georgia shows that the power provided by the new plants would be more expensive per kilowatt than several alternatives, including energy efficiency measures, renewable energy sources such as biomass and wind, and new natural gas plants.

Public financing for energy alternatives should be focused on fostering innovation and achieving the largest possible reduction in heat-trapping emissions per dollar invested—not on promoting the growth of an industry that has repeatedly shown itself to be a highly risky investment. The industry has failed to prove that things will be different this time around: soaring, uncertain costs continue to plague nuclear power in the 21st century. Between 2002 and 2008, for example, cost estimates for new nuclear plant construction rose from between $2 billion and $4 billion per unit to $9 billion per unit, according to a 2009 UCS report, while experience with new construction in Europe has seen costs continue to soar.

(3.4.2)Environment

The environmental impact of nuclear power results from the nuclear fuel cycle, operation, and the effects of nuclear accidents.

The greenhouse gas emissions from nuclear fission power are much smaller than those associated with coal, oil and gas, and the routine health risks are much smaller than those associated with coal. However, there is a "catastrophic risk" potential if containment fails, which in nuclear reactors can be brought about by over-heated fuels melting and releasing large quantities of fission products into the environment. The most long-lived radioactive wastes, including being evacuated from a 20 km exclusion zone set up around the power plant, similar to the 30 km radius Chernobyl Exclusion Zone still in effect.

Chapter 4: Design calculation:-

(4.1) Size and Shape:

There is renewed interest in Member States in the development and application of small and medium sized reactors (SMRs) having and equivalent electric power of less than 700 MW (e) or even less than 300 MW (e). At present, most new nuclear power plants under construction or in operation are large, evolutionary designs with power levels of up to 1700 MW (e), building on proven systems while incorporating technological advances. The considerable development work on small to medium sized designs generally aims to provide increased benefits in the areas of safety and security, nonproliferation, waste management, and resource utilization and economy, as well as to offer a variety of energy products and flexibility in design, sitting and fuel cycle options. Specifically, SMRs address deployment needs for smaller grids and lower rates of increase in demand. They are designed with modular technology, pursuing economies of series production, factory fabrication and short construction times. The projected timelines of readiness for deployment of SMR designs generally range from the present to 2025–2030. The objective of this booklet is to provide Member States, including those considering initiating a nuclear power programmed and those already having practical experience in nuclear power, with a brief introduction to the Advanced Reactors Information System (ARIS) by presenting a balanced and objective overview of the status of SMR designs. The Indian pressurized heavy water reactor (PHWR) programmer consists of 220, 540 and 700 MW (e) units. At present, India is operating sixteen 220 MW (e) units at five atomic power stations.

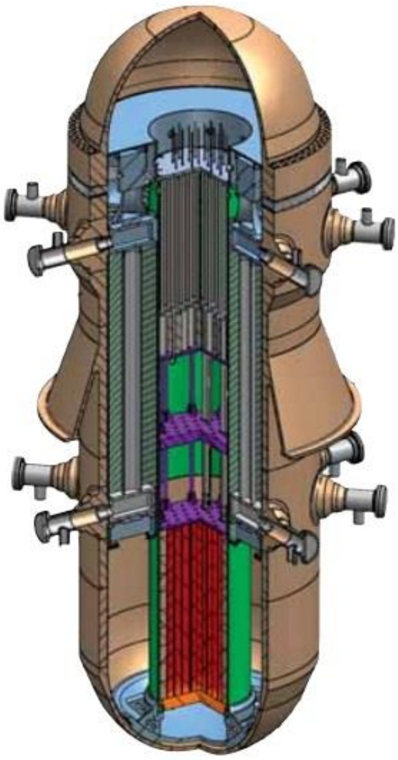


Fig.(4.1.1) Size and Shape

Fig.(4.1.2) Size and Shape

(4.2) Material Requirement: -

(4.2.1) U-235 Fuel Rods: - Which constitute the ‘fuel core’. The fission of U-235 produces heat energy and neutrons that start the chain reaction.

(4.2.2) Moderator: - Which slows down or moderators the neutrons. The most commonly used moderator is ordinary water. Graphite rode are sometime used. Neutrons slow down by losing energy due to collision with molecules of the moderator.

(4.2.3) Control Rods: - Which control the rate of fission of U-235. These are made of boron-10 or cadmium, that chain reaction is prevented from going too fast.

(4.2.4) Coolant: - Which cools the fuel core by removing heat produced by fission. Water used in the reactor serves both as moderator and coolant. Heavy water is even more efficient then light water.

(4.2.5) Concrete shield: - Which products the operating personnel and environments from destruction in case of leakage of radiation.

(4.3) Sketches: -

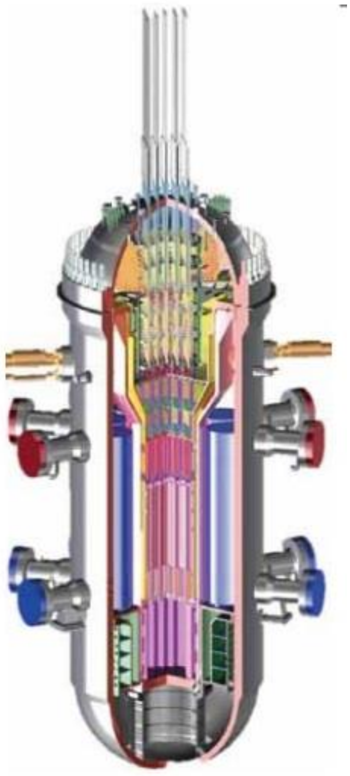


Fig. (4.3) sketches

Chapter 5: Measuring Instruments/Techniques:-

(5.1)There are five methods for detection and measurement of radioactivity:

(5.1.1) Cloud chamber: - This technique is used for detecting radioactivity. The chamber contains air saturated with water vapor. When the piston is lowered suddenly, the gas expands and is super cooled. When alpha and beta particles of water condense, the trail or cloud thus product marks the track of the particle. The track can be seen through can be seen through the window above and immediately photographed. The bubble chamber method gives better photographs of the particles tracks.

(5.1.2) Ionization Chamber: - This is simplest device used to measure the strength of radiation. An ionization chamber is fitted with two metal plates separated by air. When radiation passes through this chamber, it knocks electrons from gas molecules and positive ions are formed. The electrons migrate to the anode and positive ions to the cathode

Gives the strength of radiation that passes through ionization chamber. In an ionization chamber thus a small current passes between the plates. This current can be measured with an ammeter, and called Dosimeter, the total of electric charge passing between the plates in a given time is measured. This is proportional to the total amount of radiation that has gone through the chamber.

(5.1.3) Geiger Muller Counter: - This device is used for detecting the rate of emission of alpha or beta particles. It consists of a cylindrical metal tube and a center wire. The tube is filled with argon gas at reduced pressure. A potential difference of about 1000 volts is applied across the electrode. When an alpha or beta particles enters the tube through the mica window, it ionization the argon atoms along its path.

The argon ions are drawn to the cathode and electrons to anode. Thus for a fraction of a second, a pulse of electrical current flows between the electrons and completes the circuit around. Each electron pulse marks the entry of one alpha particle into the tube and is recorded in an automatic counter. The number of such pulses resister by a radioactive material per minute, gives the intensity of its radioactivity.

(5.1.4) Scintillation Counter: - Rutherford used a spinthariscope for the detection and alpha particles. The radioactive substance mounted on the tip of the wire emitted alpha particle. Each particle on striking the zinc through the eye-piece. With this device it was possible to counter alpha particle from 50 to 200 per second. A modern scintillation counter also works on the above principle and is widely used for the measurement of alpha or beta particles. Instead of the zinc sulphide screen, a crystal of sodium iodide with a little thallium iodide is employed. The sample of the radioactive substance contained in a small vial is placed in a well cut into the crystal. The radiation from the sample hit the crystal wall and produces scintillation. These falls on a photoelectric cell which a pulse of electric current for each flash of light. This is recorded in a mechanical counter. Such a scintillation counter can measure radiation up to a million per second.

(5.1.5) Film Badges: - A film badges consists of a photographic film encased in a plastic holder. When exposed to radiation they darken the grain of silver in photographic film. The film developed and viewed under a powerful microscope. As alpha or beta particles pass through the film they leave a track of black particles. These particles can be counted. In this way the type of radiation and its intensity can be known. However alpha radiation darkens the photographic film uniformly. The amount of darkening tells the quantity of radiation. A film badge is an important device to monitor the extent of exposure of persons working in the vicinity of radiation. The badge film is developed periodically to see if any significant dose of radiation has been absorbed by the wearer.

Chapter 6: Comparison of Existing Techniques/Methods:-

We have seen that uranium-235 is used as a reactor fuel for producing electricity. But our limited supplied of uranium-235 is predicated to last only for another fifty years. However, no fissionable uranium-238 is about 100 times more plentiful in nature. This is used as a source of energy in the so-called breeder reactor which can supply energy to the word for 5,000 years or more.

Here the uranium-235 core is covered with a layer or ‘blanket’ of uranium-238. The neutrons released by the core are absorbed by the blanket of uranium-238. This is then converted to fissionable plutonium-239. It undergoes a chain reaction, producing more neutrons and energy.

$_{92}U^{238} + {_0n^1} = {_{94}Pu^{239}} + 2\ {_{-1}e^0}$

$_{94}Pu^{239} + {_0n^1} = {_{38}Sr^{90}} + {_{56}Ba^{147}} + 3\ {_0n^1}$

The above reaction sequence produce three neutrons and consumes and only two. The excess neutron goes to converted more uranium to plutonium-239. Thus the reactor produce or ‘breeds’ its own fuel and hence its name. Several breeder reactors are now functioning in Europe. However, there is opposition to these because the plutonium so obtained can be used in the breaded H-bomb.

This deadly device makes use of the nuclear fission of the isotopes of hydrogen. It consists of a small plutonium fission bomb with a container of isotopes of hydrogen. While the exact reaction used is a strictly guarded military secret, a fusion reaction between H-2 and H-3 may be the possible source of the tremendous energy released.

The fusion bomb produces the high temperature required for nuclear fusion triggers the H-bomb. The explosion of such a bomb is much more powerful than that of a fission bomb or atomic bomb. Fortunately, the H-bombs have been tested and not used in actual warfare. If they are ever used, it may mean the end of civilization on earth.

The material used in the mask for the safety of the workers is made up of activated charcoal. Silica gel is not used for this material formation as it is a drying agent, as compared to activated charcoal which adsorbs the radioactive gases on its surface and does not allow it to pass.

Any types of metal or alloy are not preferable to be used in the shielding of the nuclear reactor because the extreme heat of the reactor can affect the shield material by melting. Thus instead of using this, a strong concrete shield is made on the outer surface of the reactor, which is not affected much by its heat.

Chapter 7: Simulation and Analysis (software modeling), Mathematical model: -

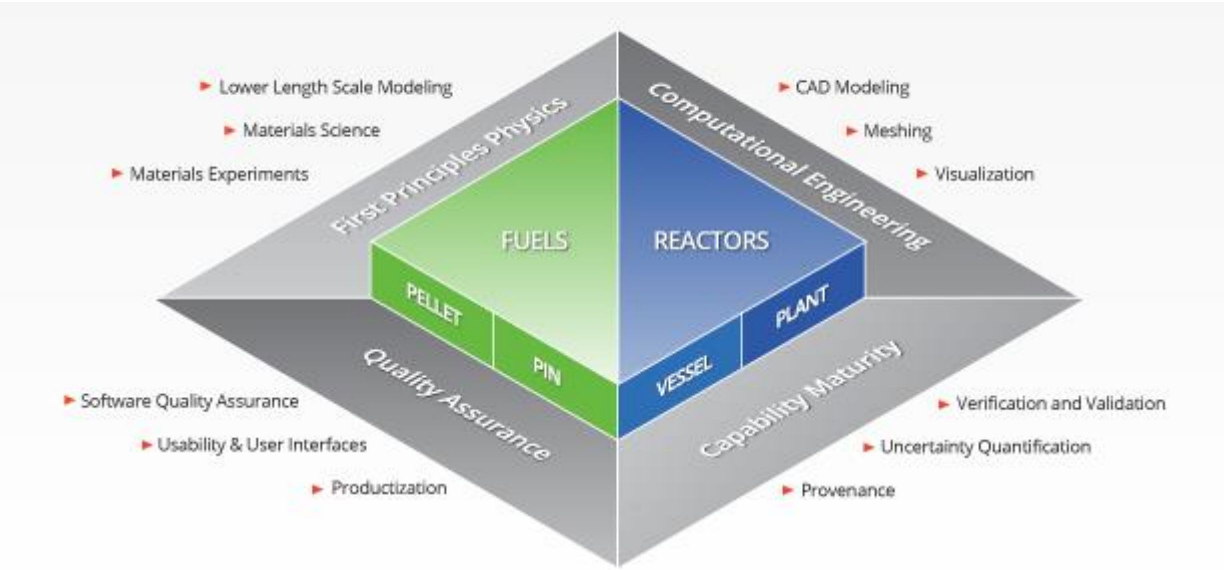


Fig (7.1) Mathematical Model

(7.1) ADVANCING THE STATE OF THE ART

Innovation advances science. Historically, innovation resulted almost exclusively from fundamental theories combined with observation and experimentation over time. With advancements in engineering, computing power and visualization tools, scientists from all disciplines are gaining insights into physical systems in ways not possible with traditional approaches alone.

Modeling and simulation has a long history with researchers and scientists exploring nuclear energy technologies. In fact, the existing fleet of currently operating reactors was licensed with computational tools that were produced or initiated in the 1970s. Researchers and scientists in NEAMS are developing new tools to predict the performance, reliability and economics of advanced nuclear power plants. The new computational tools will allow researchers to explore in ways never before practical, at the level of detail dictated by the governing phenomena, all the way from important changes in the materials of a nuclear fuel pellet to the full-scale operation of a complete nuclear power plant. For efficiency and practicality, the NEAMS program organizes its development activities into two distinct categories: the Fuels Product Line and the Reactors Product Line. Teams concentrating on the Fuels Product Line investigate the materials that comprise and surround nuclear fuel. The Reactor Product Line team focuses on developing design tools to study the full reactor system. These tools give the models and codes credibility and certainty needed for real world situations. By providing the capability to couple the Fuels and Reactors Product Lines, entirely new classes of problems can be tackled with fidelity never before attained. In this regard, the NEAMS Toolkit provides the designer with a truly predictive capability that spans the "pellet to plant".

Chapter 8: Conclusion & future scope:-

With the melodramatic history of nuclear energy in America, it’s no wonder people look at it with skepticism. But while industry management was lacking, the technology has not disappointed. New concepts now in development will not only help us through the current energy/environmental crisis, they will answer long held concerns about nuclear energy.

Nuclear power is a highly efficient and dense source of energy with no green house emissions and an abundant supply of fuel. But the industry has been plagued by poor management and a communication strategy of tech-babble. There are some valid concerns about safety associated with nuclear energy, but many of the most popular ones are not justified.

Many people are concerned about the radiation risks of living near a nuclear reactor. Thankfully, these risks are overstated. The amount of radiation you get from walking past an X-ray room in a hospital would not be acceptable for workers at a nuclear plant.

What if someone crashes a plane into the reactor? That would be terrible, but not because of radiation leaks. All nuclear plants in America have been retrofitted with redundant safety systems, including ones that make them passively safe. This means even if everybody at the plant is asleep when something terrible happens, natural forces will cause the reaction to shut down.

What about the Three Mile Island accident in 1979? In the worse nuclear reactor “disaster” in our nation's history, the physical plant failure released no radiation thanks to redundant safety systems, but the communication failure was catastrophic. Authorities did little to explain to the public what had happened. And the resulting safety measures put in place in all reactors were largely ignored. This incident was the beginning of the end of open discussion about nuclear energy.

Periodic stupid decisions by plant operators about how to deal with low-level waste have also damaged the credibility of the entire nuclear industry.

The concerns about high-level waste in Yucca Mountain are valid. We can't say what is going to happen in a thousand years. And with current technology, all we can do is sit on it. But that's not to say we don't have a plan.

The Generation IV International Forum (GIF) comprises scientists from 10 nations cooperating on development of advanced nuclear reactors. These concept reactors were designed with several goals in mind including proliferation resistance, improved safety, elimination of high-level waste, and sustainability.

Several of the Gen IV concepts are called fast reactors. These reactors will eliminate the production of high-level waste by using it as fuel. Fast reactors, such as the Sodium-cooled Fast Reactor (SFR), will be able to consume spent fuel from other reactors, and conceivably the waste now stored in Yucca Mountain. The resulting low-level waste will completely decay in much more manageable time frames.

Another Gen IV concept reactor is called the Very High Temperature Reactor (VHTR). The high temperatures in this reactor will allow it to excel at applications other sources of energy would be ineffective at, such as high volume production of hydrogen to be used in vehicles and home heating, and manufacturing steel and aluminum.

These concepts include built-in redundant active and passive safety systems. The life cycle of nuclear fuel will ensure that weapons grade material will never be isolated to minimize proliferation of nuclear weapons.

Gen IV reactors could be ready for commercial use as early as 2030, depending on funding of research. Intermediate designs can be implemented before that. Fortunately, these concepts have received vigorous international support so far.

Nuclear energy will be most effective as part of a broad portfolio of energy sources. Wind and solar energy have the potential to be very affordable and portable solutions. Nuclear can meet needs other sources would be poorly suited to, such as efficiently producing hydrogen, metallurgy, and efficient production of electricity on large scales.