Study on

ALPHA AND BETA COUNTING SYSTEM, NUCLEAR REACTOR SYSTEM AND IT'S SAFETY FEATURES AT KUDANKULAM NUCLEAR POWER PROJECT

Submitted to Mahatma Gandhi University

In partial fulfillment for the award of

Bachelor of Science *in PHYSICS*

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CERTIFICATE

This is to certify that the project report entitled **"STUDY ON ALPHA AND BETA COUNTING SYSTEM , NUCLEAR REACTOR SYSTEM AND IT'S SAFETY FEATURES AT KUDANKULAM NUCLEAR POWER PROJECT"** is an authentic record of the project work carried out by **JERIN SAJI (PRN: 160021042924)** in partial fulfillment of the requirement for the award of the B.Sc. Degree in Physics of Mahatma Gandhi University under my guidance and supervision during 2016-2019.

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Valued by……………….

Date……………………..

DECLARATION

I do hereby declare that the project entitled **" STUDY ON ALPHA AND BETA COUNTING SYSTEM , NUCLEAR REACTOR SYSTEM AND IT'S SAFETY FEATURES AT KUDANKULAM NUCLEAR POWER PROJECT"** is an authentic record of the work carried out by me during the course of my B.Sc under the guidance and supervision of Dr. ISON V.VANCHIPURAKAL , Department of Physics , St Thomas College Palai in partial fulfillment of the requirements for Bachelor degree in physics of Mahatma Gandhi University , Kottayam. I also declare that no part of this work has previously formed the basis of the award of any degree , diploma, fellowship or any other similar title or recognition.

Palai

10-02-2019 **JERIN SAJI**

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ABSTRACT

Koodankulam Nuclear Power Plant is the single largest nuclear power station in India, situated in Koodankulam in the Thirunelveli district, Tamilnadu. KKNPP uses the advanced version of Russian developed water-water power reactor. The safety relies on naturel factors such as pressure differentials, gravity or naturel convection, to ensure production against malfunctions during emergency situations. KKNPP has been a controversial projects since its inception, with protests by local residents and various activists. This project was undertaken to have a study on the safety features at the plants and for the analysis of radioactivity around the plant site.

NUCLEAR POWER PLANT

A nuclear power plant (NPP) is a thermal power station in which the heat source is one or more nuclear reactors. As in a conventional thermal power station the heat is used to generate steam which drives a steam turbine connected to a generator which produces electricity. As of February 2nd, 2012, there were 439 nuclear power plants in operation through the world. In nuclear power plants, different types of reactors, nuclear fuels, and cooling circuits and moderators are used.

Nuclear Reactor:

It is a device to initiate and control a sustained nuclear chain reaction. 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 external impacts.

Fissionable Material:

The fissionable material or nuclear fuel is generally ${}_{92}U^{235}$. In some reactors Plutonium-239 is also used. The uranium pellets are kept in the pencil of zirconium cylinders. In KKNPP the fuel used is enriched uranium.

Moderator:

It is used to slow down the neutron produced by nuclear fission. Generally graphite, light water (D_2O), etc. are used as moderators. In KKNPP the light water are used as the moderator.

Control Rods:

Materials like cadmium or boron are very good absorbers of neutron and are used to control the chain reaction. When the rods are completely pushed into the fuel, the neutrons are absorbed to such an extent that the chain reaction stops. The more the rods are withdrawn stronger is the intensity of the chain reaction. Therefore by adjusting the position of these rods, the fission reaction in the reactor can be controlled.

Coolant:

A material used to absorb the heat generated in chain reaction is a coolant. Liquid sodium and heavy water are the most commonly used coolants. The heat carried by the coolants is used to convert water into steam. The steam produced runs conventional turbines to produce electricity.

Pressuriser:

A pressuriser has following functions: -

1. Maintain the required coolant pressure during steady-state operation, limit pressure changes.

2. Changes caused by thermal expansion and contraction during normal load transients, and prevent primary coolant pressure from exceeding safe limits under all operating conditions.

3. Take care of reactor coolant volume changes during system heat up and cool down.

4. Heating up and building up pressure in the reactor coolant system during start up.

Neutron Reflector:

It is a material surrounding the fuel and moderator to reflect the escaping neutrons back into the reactor.

Shielding:

The radiations emitted during nuclear fission reactions are dangerous and harmful to living beings. As a protection against this, the reactor is usually surrounded by a thick lining of steel or lead which in turn is surrounded by concrete walls of thickness about 2 to 2.5-meters.

Cooling Tower:

It is a structure which is used to cool the water from the turbine section.

VARIOUS TYPES OF NUCLEAR REACTORS CONTRIBUTING POWER GENERATION

There are two basic types of reactors, those wherein the neutrons produced in the fission process are slowed down for facilitating further fission of uranium. These reactors are called slow neutron reactors or Thermal reactors. In such reactors, the uranium (Natural) is dispersed in a slowing down medium (Moderator), which can be graphite, ordinary water (of high purity, called light water in nuclear parlance) or heavy water. In a Fast reactor, the fission process takes place with high-energy neutrons, not requiring a moderator. But it is necessary to use concentrated fissile 1natcrials such as highly enriched uranium or plutonium.

Removal of heat from thermal reactors is done with coolants such as carbon dioxide gas or light water or heavy water. In fast reactors, it is necessary to employ a coolant such as molten sodium.

Among thermal reactors, there are two basic types, those that can use natural uranium as fuel and those that require enriched uranium as fuel. Naturally occurring uranium has two components U235, present to the extent of one part in one hundred and forty parts, which is fissionable, and U238, which is not fissionable. But U238 gets converted to artificially created fissionable material plutonium 239, after irradiation in a reactor.

In the early days of nuclear development, enrichment of uranium, was done to produce weapon grade U235. The US, USSR took up development of nuclear propulsion reactors for submarines and these reactors used enriched uranium as fuel and light water as coolant and moderator. These reactor designs were scaled up to provide designs for production of electricity. Such reactors are called Light Water Reactors (LWR) in the west and VVER in the Soviet Union. Typically, these reactors use uranium enriched to between 3 and 5 percent.

The LWRs developed in the U.S. have two variants; those that produce steam in the reactor vessel are called Boiling Water Reactors (BWR) and those where the hot water from the reactor produces steam in external steam generators are called the Pressurised Water Reactors (PWRs).

Canada worked on another reactor design that could use natural uranium as fuel with heavy water as moderator and coolant. The Canadians call it CANDU reactor and the international nuclear community calls it the Pressurised Heavy Water Reactor (PHWR).

India chose the PHWR system developed in Canada and cooperated with the latter on its second nuclear power station located in Rajasthan. India had chosen a two-unit BWR station designed by the U.S. for the first nuclear power station located at Tarapur, based on international competitive bidding.

Apart from Canada, India is one of the producers of heavy water in industrial quantities and has developed on its own a number of processes for the purpose. India produces all special materials, such as zirconium, and all equipment for PHWRs.

Kudankulam project is a Rs.140 billion Mega Project- The biggest ever under taken by NPCIL. It is a joint venture between India and Russia. The supply of equipments, components, and materials being under taken by Russian Federation.

There are two units being set up at Kudankulam with a gross capacity of 1000 MWe each belonging to Pressurised Water Reactor family. This type of water cooled water moderated reactor VVER (Voda Voda Energy Reactor i.e. Water cooled Water moderated Reactor) in Russian Nomenclature uses slightly enriched Uranium as a fuel.

DETAILS OF KUDANKULAM NUCLEAR POWER PLANT

The Kudankulam site is located along the coast of Gulf of Mannar, 25kms north-east of Kanyakumari, in Radhapuram Taluk, Tirunelveli-District in Tamilnadu. The Kudankulam site was found to be most suitable one on account of the following considerations:

The site has hard rock at reasonable depth providing good foundation conditions.

1. The site is in Seismic Zone II (as per Indian Standards Classification) which is associated with low seismic potential.

2. The site is not subject to severe cyclonic storms, tidal waves and tsunami. The maximum flood level is determined to be about 6 meters and plant structures are located above this level.

3. Large quantity of sea water is available for condenser cooling and dilution of effluents.

4. There is no population within the exclusion zone of 2 km from the proposed plant site. This land is mostly barren with no agricultural produce. The population density in the area of 2 km to 10 km is also low. There are no large population centers within 30 km radius around the plant.

5. There is no danger to the safety of the nuclear power station from man-induced events such as air-craft impact, toxic gas release, chemical explosion, industrial or military accidents.

The Reactor plant has three major loops:

a) The coolant circuit, or nuclear steam supply system comprises of reactor itself.

b) Primary coolant pump.

c) Steam Generator and associated pipes and valves.

Four such circuits are connected to Reactor Pressure Vessel. Since the Boiling point of water is 100 degrees centigrade and the temperature of coolant rises to 322 degrees centigrade in the Reactor, the coolant is kept pressurized to inhibit its boiling, by a pressuriser, connected to one of the loops. The water in the Primary circuit is slightly radioactive, therefore, the close loop is kept isolated from the environment. The hot coolant transfers its heat in the Steam Generator to water circulating in another loop called Secondary cycle. Thus, the Steam Generator has two sides, the primary side and the secondary side.

The secondary side comprises Steam Generator, Turbine, Moisture separator and reheater, condenser, feed water pump. The secondary circuit does not contain radioactivity, though it is also a closed loop and isolated from the environment. The steam produced in Steam Generator is fed to a set of Turbines, which drive the Generator to generate electricity. The steam from the Turbine is exhausted in to a condenser where it is cooled and condensed. The condensate is pumped back to the Steam Generator. The condenser cooling is accomplished by a third loop, condenser cooling system) which draws cooling from the Gulf of Mannar. It is this (third) circuit which is exposed to the environment.

The need for nuclear power plants:

It is found that, fossil fuels are by far the largest source of electricity in the world today. Coal, alone, accounts for about 52% of electric power. The present statistics show that, the coal resources are getting depleted at a faster rate and they also add to the environmental issues. With the limited resources of coal and oil available in the country and with growing global concerns of green house gases generated by, fossil fuel fired stations, nuclear power will be called upon to play a greater role in medium and long term perspective.

The following points present some of the major advantages:

- Nuclear power plants emit far fewer atmospheric pollutants than the competition. They do not emit any sodium dioxide, nitrogen oxide or dust from burning fuel.

- Nuclear power plants do not emit any carbon dioxide, the gas widely believed to be the primary contributor to the greenhouse effect. The greenhouse effect, of course, causes global warming. In the United States, coal-fired power plants release approximately 2 billion tons of carbon dioxide each year. However, the limit and even the existence of global warming is still the subject of much debate.

- Nuclear power plants only need refuelling once every year to 18 months. The new store of fuel constitutes about 2 metric tons, or 6 truckloads of uranium. Coal power plants require a new trainload of about 100 tons of coal every day.

- Since nuclear power plants use so little fuel, the volume of nuclear waste is much smaller than the volume of waste from fossil fuel power plants. Even though nuclear waste is highly radioactive, its small volume enables safe isolation from society.

- Nuclear power is economically competitive with coal, and generally considered much cheaper than oil or natural gas. In one joint study by several agencies and independent groups, 11 out of 19 counties found nuclear power to be at least 10% cheaper than coal-fired power. 7 more of the countries found the prices to be nearly equivalent.

Safety Features:-

✓ The most important one is the so called "negative power coefficient" wherein any increase in reactor power is self-terminating. Thus, events which may cause large power increase and damage the reactor are extremely unlikely.

✓ Another inherent characteristic called "negative void coefficient" causes the reactor to shut down, if there is loss of water from the reactor core.

✓ Reaction protection system, Shut off rod system, Quick boron injection system, Emergency core cooling system, Emergency electric supply system, Passive heat removal system.

✓ Presence of several physical barriers. These barriers are provided to arrest the leakage of radioactive elements during any extreme circumstances

The electrical systems for two units, each of l000 Mwe of Kudankulam Nuclear Power Plant mainly consists of Power output system and Station Auxiliary Power Supply System.

POWER OUTPUT SYSTEMS:

The electric power, generated by turbo-generators of both the units at 24kV, 3 phase, 50 Hz, is stepped up to 400 kV through respective generator transformers and evacuated through four 400 kV transmission lines. For reserve source of power to auxiliaries of NPP, Kudankulam NPP is connected to 220 kV substations by two separate 220 kV transmission lines 400 kV & 220 kV buses at Kudankulam NPP are interconnected by means of two interconnecting autotransformers. Normally the generated power is evacuated through 400 kV transmission lines. However, since 400 kV & 220 kV systems are interconnected, power can flow through 220 kV lines depending on generation and load scenario in the grid.

Major Components:

Generator

Isolated Phase Bus Duct (IPBD)

Generator Circuit Breaker (GCB)

Generator Transformer (GT)

Gas Insulated Bus ducts (GIBD)

Switchyard

Gas Insulated Switchgears (GIS)

Interconnecting Autotransformer

SAFETY FEATURES OF KKNPP

1. INTRODUCTION

The Kudankulam Nuclear Power Project (KKNPP) is an Indo-Russian joint venture for establishing a nuclear power station with 2 units (KKNPP-1&2) of 1000 MWe Pressurized Water Reactors of VVER design at Kudankulam in Tamilnadu. The proposed Power station is covered by the International Atomic Energy Agency (IAEA) safeguards , on lines with existing stations like Tarapur-1&2 and Rajastan-1&2 built in collaboration with USA and Canada respectively. The project site has the required clearances from Atomic Energy Regulatory Board and also by various other statutory authorities in the State and Centre.

The VVER reactors being established at Kudankulam belong to the family of advanced Pressurized Water Reactors (PWRs). Presently 434 nuclear reactors are under operation in the world and about 269 of them belong to the PWR family including 55 VVERs . Among the 64 reactors under construction worldwide, 53 are PWRs including 10 VVERs.

The activities towards establishing the two reactors were progressing satisfactorily till the last week of July 2011 when a section of the population in the neighborhood, in association with an organization called, People's movement against nuclear energy (PMANE), started an agitation against the project and demanded the closure of KKNPP. Due to this agitation, project work at the site has been adversely affected.

The Government of India constituted a 15 member Expert Group (EG) to provide clarifications on the issues raised by the agitators and allay their fears. The EG has been asked to do this by interacting with the forum provided by the State Government comprising of 2 State

Government nominees and 4 representatives of the people . The EG observed that several statements by protesting leaders in public meetings , news items the media and the demand for closure of the nuclear power plant are mainly due to in misinterpretation of the global trend on the use of nuclear energy for power generation, lack of appreciation of the 4 decades of Indian experience in establishing and operating nuclear plants , misunderstanding and lack of knowledge on the levels of radiation in the neighborhood of NPPs and its impact on health , unfounded fears on the health of present and future generations , inadequate public awareness of the advanced design and safety features of proposed nuclear reactors at Kudankulam , imaginary adverse impact on the livelihood of people in the neighborhood etc.

This report has been prepared based on published literature, detailed information obtained from the records provided by NPCIL and inspection of the site . The report is finalized with full agreement of all project members.

2. Safety features of KKNPP against TMI, Chernobyl, Fukushima type severe nuclear accidents

Three Mile Island (TMI) in 1979 , Chernobyl in 1986 and Fukushima in 2011 are the nuclear power plant (NPP) accidents involving damage to the reactor core that have occurred in the nearly 60 year history of NPP operation in the world. TMI was rated at level-5 whereas Chernobyl and Fukushima were rated at level-7 of the International Nuclear Event Scale (INES). The INES has 7 levels in which levels 1 to 3 are assigned to safety significant incidents and levels 4 to 7 are for accidents , with level -7 signifying accidents with highest severity.

The nuclear industry has a well-structured system of using operating experience feedback. All incidents and accidents are carefully analyzed to identify the causative factors and this information is used , as applicable , in NPPs towards making necessary design and operational improvements . In India also , all safety significant events that occur in our NPPs as also in NPPs abroad , including accidents , are examined in detail and appropriate safety improvements in hardware , procedures and operator training are implemented. Further, the key operating personnel in our NPPs, unlike in many other countries, are graduate engineers who undergo rigorous theoretical and in-plant training before they are authorized to perform the NPP operating functions. They are also required to be periodically reauthorized after receiving refresher training . Consequently the Indian operators are better placed to correctly interpret off-normal plant situations and adopt the most appropriate course of corrective action. This ability of Indian NPP operators has been amply demonstrated on several occasions.

A. The TMI accident and KKPP

TMI-2 , a 900 MW pressurized water reactor in USA , was operating at near full power in the morning of 26 April 1979 when the pumps feeding water to the steam generators tripped due to some electrical or mechanical fault . The turbine and reactor tripped as designed. Two trains of auxiliary feed water pumps had been provided to charge water to the steam generators in the event of failure of the main feed water pumps . Unfortunately the valves at the discharge of these pumps had been left in closed position after carrying out maintenance work earlier rendering the pumps ineffective . With no heat removal in the steam generators , the reactor coolant temperature and pressure started rising due to decay heat from the nuclear fuel . This resulted in the relief valve located on top of the coolant system pressurizer to open to relieve the pressure . The relief valve failed to close back after the pressure had come down, leading to continued loss of coolant system water inventory. However , the indication in the control room showed that the relief valve had closed as the indication had been derived from the instrument signal to the valve rather than from the physical position of the valve itself . As the coolant pressure came down , emergency water injection to the coolant system started as per design but the operators terminated the injection after some time since the water level instrument was showing the pressurizer as full and they were worried about the system getting over pressurized. In reality, while the pressurizer was full of water , the coolant system had been heavily voided on account of boiling of the coolant.

In the absence of heat removal from the reactor coolant and no make up for the depleting coolant inventory , fuel in the reactor core overheated and partially melted . The accident was terminated after the operators closed a block valve on the pressurizer relief line and restored emergency water injection . Small amounts of radioactivity were released to the environment from the reactor ventilation system exhaust stack when the reactor vessel was vented to the atmosphere to release hydrogen that had got generated from the reaction between steam and the overheated zirconium cladding of the fuel. The reactor vessel did not breach and the molten fuel was retained within the vessel. The reactor containment building also remained intact and hence there was no release of radioactivity at the ground level . There was no death , injury or any over exposure to radiation of plant workers or the public . TMI accident happened due to a combination of equipment failure , lack of sufficient instrumentation and operator error.

The KKNPP has been provided with four 100% capacity trains for each of the safety functions which include the auxiliary feed water pumps. There is an elaborate pre-startup check list through which it is ensured that all safety systems are poised and are in their design intended configuration before reactor start up can be taken up . The pressurizer instrumentation has been sufficiently augmented and improved to provide clear and unambiguous indication of water level and status of all valves connected to the pressurizer . An elaborate set of emergency operating procedures has been developed to cater to all conceivable off-normal situations and the operators are thoroughly trained in their execution which includes training on a full scope training simulator . Further, the KKNPP design has several advanced design safety features like the provision for decay heat removal by natural convection cooling by the Passive Heat Removal System (PHRS). The PHRS functions even in the absence of all power supplies as also with no water injection to the steam generators and the reactor coolant system available. An accident of the type that occurred at TMI-2 is therefore not conceivable at KKNPP.

B. The Chernobyl accident and KKNPP

The Chernobyl-4 NPP is an RBMK-1000 MW, graphite moderated, vertical channel type, water-cooled and boiling water reactor. The fuel is located in ~ 10M long vertical pressure tubes and coolant water flows through the pressure tubes from bottom to top. The pressure tubes (1660 nos.) are located inside vertical channels in a graphite stack and mixture of nitrogen and helium flows through the gap between pressure tubes and graphite to cool the graphite and prevent it from coming in contact with air. Heavy radiation shields are placed at top and bottom of the reactor core. A partial containment is provided for reactor block only unlike a full containment building in modern NPPs. There are 211 water cooled control rods (C/R), each rod with a high neutron absorber section at top and a graphite section below it. With C/R in withdrawn condition, the graphite section resides in the active region of the core. In the lowest part of the C/R, water is present over a small height below the graphite section. When C/R is inserted, the neutron absorber section replaces the graphite section in core, thus increasing the rod's capability to absorb neutrons to reduce reactor power. A test was planned to check if, on loss of grid power, the energy stored in the rotating turbine can be used to generate sufficient electricity to operate emergency core cooling pumps (before the station DGs come on line).

Unit-4 was scheduled for shut down on 25 April 1986 for normal maintenance activities. Shut down of the reactor was started but had to be stopped with reactor at 50% full power (FP) as per grid requirement and it continued to operate at 50% FP for about 20 hrs. Lowering of power was resumed at midnight to stabilize the reactor at 20-30% FP (as per test procedure) but power fell to 1% FP (due to xenon build up during extended operation at 50% power). Control rods were raised to compensate for xenon and with this action power could be stabilized at 7% FP.

The test was started by closing steam inlet to turbine to start the process of slowing down the turbine generator. An additional cooling water pump was started as per test procedure which caused steam pressure to fall. Reactor trip on low steam pressure had been bypassed and emergency core cooling system had been disabled as per test requirement. More control rods were withdrawn to raise reactor power and steam pressure (consequently only 7 control rods were 'in' against the safety requirement of at least 15 rods to be 'in' at any time). The rise in steam pressure, in combination with low operating power, created a core configuration where overall power coefficient was positive. This meant that any increase in power will drive the reactor power to rise further and can cause power surge. As steam pressure rose, the operator tried to manually trip the reactor by dropping control rods. As control rods started moving down, their graphite sections first replaced the water below. This caused the neutron population in the core and therefore the reactor power to surge as graphite absorbs much less neutrons compared to water. The power surge resulted in sudden and very high increase in fuel temperature leading to the rupturing of fuel rods. Interaction of overheated fuel with water caused steam explosion and further heating of fuel caused it to vaporize and gave rise to explosion of fuel vapors. The top shield got lifted due to the pressure wave from the explosions and damaged the pressures tubes severely. The graphite stack now got exposed to oxygen forming flammable carbon mono-oxide which ignited and caused graphite fire. The explosions and the large graphite fire destroyed the reactor completely.

The Chernobyl accident was caused by design deficiencies and an inadequate test procedure, coupled with several violations of the prescribed procedure by operators who were not adequately trained for this specific task. This placed the reactor in a configuration that was highly vulnerable to becoming unstable and not amenable to control.

KKNPP is a pressurized water reactor, cooled and moderated by light water, and its core containing the nuclear fuel is located inside a pressure vessel. There are no pressure tubes, no graphite moderator and no boiling of water in the core. The control rods in KKNPP do not have any graphite follower and therefore, unlike in the case of Chernobyl, cannot cause any power surge. The design ensures that in any configuration, the power coefficient of the reactor remains negative. The KKNPP reactor is located inside an airtight primary containment building which is surrounded by the secondary containment. There are also other design features in KKNPP which assure adequate core cooling under all conceivable off normal conditions including total loss of electric power. Even for the hypothetical case of a core melt down, a core catcher is provided where the molten core is retained and cooled and the double containment ensures that there will be no significant radiological impact in the public domain.

The KKNPP is of a most modern design and its design and safety features have almost nothing in common with Chernobyl as explained above. Therefore, it is just not conceivable that even an accident scenario similar to Chernobyl, let alone the accident per se, can develop in KKNPP.

C.The Fukushima accident and KKNPP

Fukushima-I NPP, located on northeast coast of Japan, has 6 units of boiling water reactors. An offshore earthquake of magnitude-9 with its epicenter ~ 130 KM from the NPP, struck on 11 March 2011. The quake also generated large tsunami waves. Units-1, 2&3 got shut down automatically (units-4, 5&6 were already in shut down state). Grid power supply was lost due to the earthquake. As per design, emergency diesel generators (EDGs) of the NPP started automatically to supply essential AC power. Batteries of the NPP supplied essential DC power. About 14m high tsunami waves hit the plant after ~ 45 minutes. Due to extensive flooding caused by tsunami, the EDGs failed. DC batteries drained out in ~1 hour leading to total loss of power supply at units-1, 2, 3 & 4. An air cooled back-up DG for units-5 and 6 located at a high elevation that was provided as a retrofit to ensure availability of emergency power in the event of a strong tsunami, continued to function. With this power, the reactors of units-5&6 could be cooled. Units-1&2 and units-3&4 were also provided with similar back-up air cooled DGs but unfortunately these were located at a lower elevation and hence failed due to flooding at the site from tsunami.

With no power available, reactor cooling in units-1, 2&3 was lost resulting in overheating and damage of uranium fuel (fuel of unit-4 had been unloaded at that time into spent fuel storage pool located adjacent to reactor vessel). It took a long time and large effort to restore cooling to the overheated fuel cladding made of zirconium reacted with water producing hydrogen which escaped into reactor buildings. Equipment had been provided to recombine the hydrogen with oxygen in the air but did not work in the absence of power supply, leading to hydrogen explosions. Some radioactivity escaped from the plant and evacuation of population up to 20 KM radius around the NPP and restrictions on consumption of food, milk etc. was imposed as a matter of abundant caution. However, no member of public received radiation dose more than the prescribed limit. With significant efforts over a considerable length of time, the reactors could be secured with adequate cooling. Cleaning of the areas around the plant is in progress to enable people to return to their homes. Fukushima accident happened due to a combination of extreme external events leading to complete loss of power supply. In the case of KKNPP the nearest off shore fault line (Andaman-Nicobar-Sumatra fault) capable of generating a tsunami, is located about 1500 KM from KK. Thus, unlike in the case of Fukushima, there is no possibility of a tsunami and an earthquake occurring together at KKNPP

The maximum flood level at KKNPP site on account of the strongest tsunami or storm surge has been determined as 5.44M above the mean sea level. Keeping a further safety margin of 2M, the safe grade level for the site has been decided as 7.44M above the mean sea level. All important structures and components including emergency power supply equipment at KK are located well above this elevation. Thus, unlike in Fukushima, where the emergency power supply equipment failed due to flooding from tsunami, even the strongest tsunami cannot disrupt the emergency power supply at KK and cooling of the reactors can be maintained without interruption.

Even assuming that all power supplies are lost due to some unforeseen reason, cooling of the reactors at KK can still be maintained by the Passive Heat Removal System (PHRS) that is provided as a further measure of defense in depth. The PHRS works on the principle of natural convection cooling and, unlike in Fukushima, does not need any power supply at all. Heat from the reactor is transferred to the large quantity of water present on the secondary side of the steam generators and this water in turn is cooled by atmospheric air in the coolers provided at a height on the outside of the outer containment. Even under a hypothetical accident condition of core melt, the molten core is retained and cooled in a core catcher that is provided below the reactor vessel. Radioactivity from the damaged or molten fuel cannot come out of the inner containment building inside which the reactor is housed. This is an air tight pre-stressed concrete building designed for maximum pressure generated from the worst possible accident and is periodically tested for its leak tightness. Any small leaks from cable and pipe penetrations are retained by the outer containment building. The Fukushima NPP did not have any secondary or outer containment.

The catalytic hydrogen re-combiners provided at KK are of the passive type and they do not require any power supply for their functioning. At Fukushima the hydrogen re-combiners needed power supply for their working and since power supply was not available, they failed to function resulting in hydrogen explosions.

Fukushima NPP is of a much older design and did not have several of the safety features that are provided in KKNPP which is of a most modern design. As brought out above, it is not conceivable that any accidents of the type that occurred at TMI, Chernobyl and Fukushima can take place at the KKNPP. Further, the KKNPP has advanced design safety features which provide assurance of reactor cooling and containment of radioactivity under even hypothetical accident conditions.

KKNPP Reactor Design and Safety

A. VVER is a pressurized light water cooled and moderated reactor with four independent cooling loops. The reactor has horizontal steam generators in each loop that gives high water storage capacity. It uses hexagonal fuel assemblies which have low enriched fuel in oxide matrix, housed in sealed Zirconium-Niobium alloy tubes.

B. KKNPP is an advanced model of the Russian VVER 1000 that adopts the basic Russian design model marked V320 with Enhanced Safety Features to make it in line with IAEA GEN III reactors. Further, certain additional safety features were incorporated like Passive Heat Removal System taking it to GEN III+ category. Russian Federation has marked KKNPP reactor as V412.

C. The safety features of KKNPP were comprehensively reviewed by a task force of NPCIL in the context of recent Fukushima accident. The report of the task force is available in the website of NPCIL and DAE.

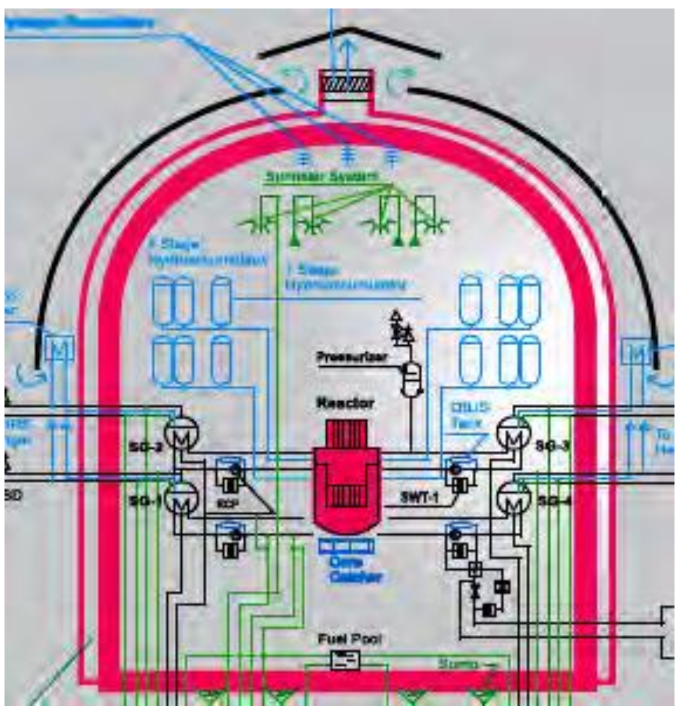
D. Salient Normal Operating Parameters of KKNPP Reactors:

- Electrical Power 1000 MWe
- Thermal Power 3000 MWt
- No. of FAs 163
- Coolant inlet temp 291°C
- Coolant outlet temp 321°C
- Coolant Pressure 15.7 MPa
- No. of Loops 4
- No. of Control Rods 103
- Pressure Maintenance by Pressurizer

E. Enhanced Safety Features:

Key Safety Features incorporated in KKNPP as required by India:

- Quick Boron Injection System
- Passive Heat Removal System
- Second Stage Hydro Accumulators
- Passive Hydrogen Re-combiners
- Annulus passive filtering system (passive system)
- Core Catcher
- Emergency Control Room.



The above systems have been developed based on extensive R & D and simulated testing by Russian design institutes. Functional performance of these systems are established during commissioning stage. These systems are described in subsequent sections.

A) Earthquake Design Basis for KKNPP

Kudankulam Nuclear Power Plant is located in Indian Seismic Zone II which is the least seismic potential region of our country. However, for designing of the Plant, detailed studies are conducted to conservatively estimate extent of ground motion applicable to the specific Site with reference to Seismotectonic and Geological conditions around it so that NPPs are designed for a SSE level earthquake which has a very low probability of being exceeded (return period of 1 in 10,000 years).

For Kudankulam NPP, the following tasks were undertaken for detailed evaluation of Site specific conditions as below:

a) Study of the seismotectonic and geological setup of the region.
b) Selection of a set of recorded accelerograms with source and site conditions resembling those at Site for computing response spectra.
c) Generation of response spectra of the selected time-histories for various values of damping and statistical analysis of the ensemble of response spectra.
d) Collection of additional information on earthquakes, regional and local geology and tectonics pertinent to evaluating fault activity and design basis ground motion parameters.
e) Integration of the above information to arrive at the Earthquake Design Basis (EDB). This involves the generation of peak ground acceleration and response spectral shapes for various components of ground motion for both S1 and S2.
f) Generation of spectral compatible accelerograms.

All potential, active and non-active faults, lineaments and seismic history within a radius 300 kms have been analyzed to arrive at the SSE and OBE levels of earthquake. As per above data, there are no faults / lineaments in the near vicinity of the site. The most intense earthquake experienced in this
300km region is the earthquake that occurred at Coimbatore (307 km) on 08/02/1900 which had an epicentral intensity of VII on the MMI scale (6.0 in the Richter scale).

Towards enhanced conservation, the high intensity earthquakes that occurred in this seismotectonic region have been assumed to act at the closest faults/ lineaments near the site in arriving at the SSE level. The Site specific response spectra for SSE at KKNPP has been derived from the envelope of these hypothetical events. Considering the above events, a rock-site-specific formula for the maximum peak ground acceleration valid for the range of magnitude and distance of interest has been derived.

B) Flood design of KKNPP

Design Basis Flood Level

The safe grade elevation of KKNPP site has been kept at 7.5 Mtr above MSL and a shore protection bund is constructed all along the shore to a height of + 8.0 Mtr to MSL.

Shore stability

No potential of shore instability exists at Kudankulam site area, as protruding rock outcrops are present all along the coast protecting the shore from erosion. Also, no historical shore erosion has been recorded in the area

Tsunami warning systems

Possible Tsunami occurrence can be known as alerts come from the following agencies:

- KKNPP is registered with INCOIS, Hyderabad (Indian National Centre for Ocean Information Service). In case of any Tsunami warnings, information in the mobile numbers of the station management will be received.
- Madras Atomic Power station, Kalpakkam has established PC based Earthquake Notification System (ENS) which gives alarm in the control room in case of an earthquake. ENS is an application which scans USGS (US Geological survey) and EMSC (European Mediterranean Seismic Centre) sites. Immediate alert will be given to KKNPP control room from Kalpakkam in case of any alarm.

C) Fish protection in intake facility

Kudankulam project uses sea water for condenser cooling for which water is drawn from intake dykes. To save the fishes from coming into the fore bay / pump house area and getting trapped, KKNPP houses a unique "fish protection system" where in all the fishes which are coming into the intake will be separated by means of a unique air curtain and "Oogee weirs" and are safely returned back into the sea. This is a unique facility to protect the marine organisms, including fish and prawns.

3. ENVIRONMENTAL IMPACTS

Impact on flora and fauna

As such the land acquired has been dry and barren and hence there is no impact on the flora and fauna inside the plant area. NEERI has conducted the base line study of the biological environment in and around KK site and is well documented.

As stated earlier, a total of 23890 plants and trees has been developed for green belting, at
KKNPP. The area covered by lawns and gardens is 16419 Square meters. Hedges accounts for 2467 running meters.

The Green Belt programme will be continued to develop a green belt in the vacant land, after assigning the plant structures of KKNPP 3 to 6. Because of the green belt developed, the area around plant and township has become a hub for migratory birds

Impact on Land

Beneficial impacts would be felt on land use pattern and topographical features of the area due to greening of the area through plantation and green belt development. Under operating conditions, there will not be any impact on the land environment as discharges are insignificant as compared to the combined natural background parameters. As of June 2011, a total of 23890 plants and trees has been developed for green belting, at Kudankulam site (KKNPP). The area covered by lawns and gardens is 16419 Square meters. Hedges accounts for 2467 Running meters and this will help to improve the quality of environment around NPP. The green belt development will be continued in future which will attract more fauna especially avian species resulting in improvement in biodiversity as evident in other nuclear power stations like Kaiga, Kalpakkam, Tarapur etc.

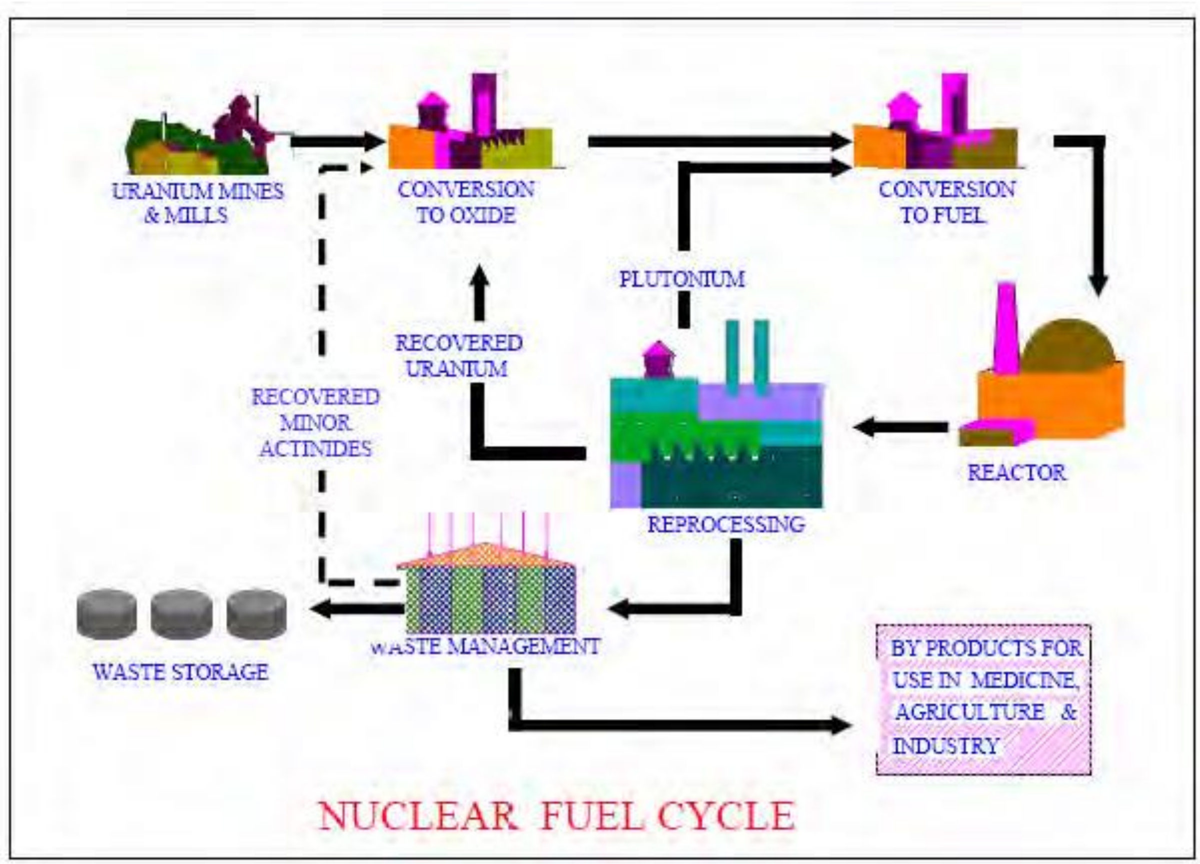
Impact on Agriculture, livestock and food security

National Environmental Engineering Research Institute (NEERI) has prepared the Environmental Impact Assessment (EIA) report and had documented the land use classification in 30 km radius of the plant site based on satellite mapping. The land use/ land cover classification indicates 8.73% area covered by vegetation, 8.73% are covered by Barren land, 23.39% area covered by scrubland, 8.52% area covered by sandy area, 0.08% built-up area, 49.68% water body including sea, river/nala etc. This is the baseline data. However data from the other nuclear power plants in the country indicate that operation of NPPs do not have any adverse impact on agriculture, livestock and food security.

Radioactive Waste and Spent Fuel Management: Principles and Practices

Management of radioactive waste in Indian context includes all types of radioactive wastes generated from the entire nuclear fuel cycle right from mining of uranium, fuel fabrication through reactor operations and subsequent reprocessing of the spent fuel. Figure depicts the entire activities across the closed fuel cycle adopted in India along with their connectivity. Besides, such wastes are also generated from use of radio nuclides in medicine, industry and research.

NUCLEAR FUEL CYCLE



In consideration to the primary objective of protecting human health, environment and future generation, the overall philosophy for the safe management of radioactive waste relies on the concepts of

i) Delay and Decay

ii) Dilute and Disperse and

iii) Concentrate and Contain

Effective management of radioactive wastes involves segregation, characterization, handling, treatment, conditioning and monitoring, prior to final storage/disposal. Radioactive wastes arise in different forms viz. solid, liquid and gaseous with variety of physical and chemical/radiochemical characteristics. Depending on the level and nature of radioactivity, radioactive wastes can be classified as exempt waste, Low & Intermediate level waste and High Level Waste. Low & Intermediate level wastes are further categorized as short lived and long-lived wastes. Radiological hazards associated with short lived wastes (< 30 years half-life) get significantly reduced over a few hundred years by radioactive decay. The high level waste contains large concentrations of both short and long lived radionuclides, warranting high degree of isolation from the biosphere and usually calls for final disposal into deep geological formation (repository).

In tune with international scenario, a coherent, comprehensive and consistent set of principles and standards are followed and practiced for waste management system. Wide range of treatment and conditioning processes are available today with mature industrial operations involving several interrelated steps and diverse technologies.

ENVIORNMENTAL MONITORING & STUDIES

At each of NPP sites, Environmental Survey Laboratories (ESL) are set up, which are operated by an independent organization viz. Health Physics Division of Bhabha Atomic Research Centre, Mumbai. At the existing NPPs sites, ESLs have been collecting and analysing radioactivity levels in the samples of various environmental matrices in the radius of 30 km from the plant site. Their reports conclude that the dose to population at the fence resulting from the existing NPPs in the country is about 1.5% of the authorized dose limit of AERB, which is a small fraction of the natural background radiation. The doses at further distances are still lower.

At NPP sites, environmental studies such as condenser cooling water discharge studies, thermal ecological studies, biodiversity conservation studies etc. are carried out for insuring compliance to environmental standards and environmental clearance stipulations from regulating agencies such as MoEF, AERB and State Pollution Control Board. These studies have demonstrated that the effect of thermal discharges from NPPs on marine ecology is confined to a small area and is reversible in nature.

1. ALPHA COUNTING SYSTEM

An alpha counting system comprises of an alpha probe and counting electronics including high voltage supply to probe, a paramplifier, amplifier, timer and scalar.

ALPHA PROBE:

Alpha probe consists of a scintillator detector made up of a thin layer of silver activated (ZnS/Ag) crystal a high performance low noise photomultiplier tube (PMT). The density of the crystal is about 10 mg/cm2. The PMT and crystal are placed in a light steel housing so as to have very low background of the order of about 0.001 cps at an efficiency of about 30%. The operating voltage is usually less than 1500V enabling the use of some scales.

PRINCIPLE:

Alpha particle incident on the (ZnS/Ag) powder spend their energy completely in raising the valence electrons into the conduction band. The electrons from the excited state return to ground state either directly or through activator sites. The loss of energy appear as visible/UV light rays when they reach ground state. Cathode of PMT is positioned in such a way that it absorbs full light energy and emits primary electrons. PMT multiplies the primary electrons and develops a current signal at the output of anode which is amplified and shaped to register it in a counter.

APPLICATION:

Environmental samples and air fitters are counted or estimation of gross alpha activity. Chemically separated and electrodeposited samples of Pu, Am and CM can also be used for radon estimation by emanometry with certain modification relating to the detector probe to accommodate a scintillation cell coupled to PMT housed appropriately.

PERFORMANCE:

The background of the system is about 0.002 cps and the efficiency for plated 219 Pu source is 25% to 30%. The efficiency is largely influenced by the thickness of samples MDA for unit volume of sample is 0.0075Bq for counting time of 5000s.

2. BETA COUNTING SYSTEM

a) G.M COUNTING SYSTEM

Beta counting systems generally utilize a medium sized sealed normal type or low background type of end window Geiger-Muller tube as detectors. Argon as counting gas and halogens or organic gas as quenching gases are used in these tubes. Beta particles incident in the gas volume through a mica window dissipate their energy in the gas atoms. Electrons produced in the process are swept to anode are collected. The signal is quite strong as the detector is operated in G.M region and does not require complicated electronics. An electronic quench unit (paralysis unit) collects these electrons and provides a measurable pulse. It also provides a selectable fixed dead time of 250 or 350 or 550 micro second. Beta counting system can be assembled by utilizing nuclear instrumentation modules like EHT unit. Paralysis unit, timer/scalar, and the power supply bin. Standalone systems are also available which contain electronic circuitry to provide required function of the above units.

CALIBRATION:

Analytical grade potassium chloride crystals are powdered after drying at 110 degree Celsius for 1 hour and uniformly spread and fixed with gelatin or collodion in an aluminium planchet. The size of the planchet is properly chosen to match the detector and window size. Strength of around 2Bq of K-40 is sufficient to give significant count rate. Natural potassium contains about 0.012 % of K-40. Higher strengths will increase the thickness of standard source causing self-absorption. The efficiency of the detector is mostly independent of energy in G.M mode of operation but attenuation due to sample thickness need to be corrected. Gas fitted GM counters normally give 15-20 % efficiency and about 0.4 cps background. The specific activity of KCl is 16 Bq/g.

BACKGROUND:

The background due to cosmic radiation and environmental radiation is reduced to some extent by employing good quality lead shielding of about 5m thickness with Al or Cut lining. Background radiation of detector materials can be reduced and therefore detectors give low background should be chosen. Detector of size 25mm X 50mm (diameter X height) would have background in the region of about 15cpm to 50cpm i.e. 5cm on shielding depending on the type of detector.

APPLICATION:

Environmental samples of different matrices can be counted after radiochemical separation to estimate the radioactivity due to beta radiation. Moderate to high active liquid samples (1-100Bq/ml) could be evaporated in planchets and counted to estimate gross beta activity (a sample volume of about 2-3ml could easily be evaporated). Air fitter samples can be directly counted to estimate gross beta activity after a delay of about are week which allows the decay of naturally occurring short half-life daughter products of radon and thoron

b) GAS FLOW BETA COUNTER USING ANTI COINCIDENCE TECHNIQUES

Generally two or three GM counters of either planar or spherical shape namely main counter or guard counter are used. The counters are mechanically arranged in such a way that background radiation due to cosmic rays and surrounding materials do not interact directly with the medium of main counter where the sample is placed without passing through the guard counters. The counters have an aluminium or gold foil window of about 1mg / cm sq. through which beta particles travels and reach the gas (Argon) chamber with isopropyl alcohol vapors and ionized medium. The signals both counters are collected through the anode wire.

PRINCIPLE

The electronic signals from both main and guard counters are fed to an anticoincidence electronic unit. The unit filters out the signal of main counter if it has a corresponding signal of the guard output in coincidence within a specified resolving time. Resolving time depends on the electronic unit used and the associated detector and electronics. It varies from 50msec to 200msec. Anti-coincidence signals from the main counter alone are fed into the scalar and recorded.

PERFORMANCE

Due to anti coincidence technique and shielding the background system is reduced to about 1-2 cpm. The efficiency of the counter is generally independent of incident beta particle, once the particle enter the chamber. However, due to absorption of energy of incident particle by the window material the efficiency get affected for different energies. The efficiency for potassium - 40 is approximately 40%. The efficiency for other beta energies of cesium -137 and strontium -90 is about 35% .The efficiency is also influenced by the thickness of sample. The efficiency for yttrium -90 is about 45%. The MDL (3 sigma) of low background beta counting system is 0.023 Bq for 3600s counting duration.

APPLICATIONS

Single radio nuclides from environmental samples of various matrices are counted using gas flow beta counter after radiochemical separation. The sample diameter of about 2cm & sample thickness of about 10mg/cm. sq. is appropriate.

AIM:

To measure the gross alpha and gross beta particle activities in given samples.

APPARATUS:

1. ALPHA COUNTING SYSTEM

Detector materials: ZnS (Ag) deposited on a transparent PMMA support

Light sealing: By light embedded coat n ZnS

Drawer assembly facilities:

(a) Placement of 25mm d1ass planchets for sample counting

(b) Placement of 55 mm dia filler paper swipes below the SS securing ring for sample counting

Efficiency: more than 30 percentage

Back ground counts /6000 sec: less than 5

Photo multiplier tube: ET9656/9956Oor its equivalent /9256B

Size: 50.8mm diameter

Operating voltage range: 900 v to 1000v

2. BETA COUNTING SYSTEM

RCS 4037

PM INPUT: (a) Amplitude: 100 mV

(b) Polarity: negative

GM Input: (a) Amplitude: 500mV

(b) Polarity: negative

Preset time: 0 to 9999

Preset count: 0 to 999999

Self-check: Internal clock source of 60 He, 5 v amplitude

EHT output: (a) 50 to 1500 v DC variable from 0 to 1500 v in steps of 1 V

(b**) Output current**: 0.5mA

(c) **Ripple:** less than 50 mV

Display: 2*16 L C D DISPLAY

Input power requirement: 230 V ac +/- 10 percentage - 50 Hz or +12 v DC

Operating temperature: 0 to 50 degree temperature

Dimension: 482*280*88.9

Weight: 5.5 kg

THEORY

Activity of a sample is the average number of disintegrations per second. Its unit is Becquerel (Bq).

Activity (A) = $(N_a/t_1-N_b/t_2)*100/\eta*1/V*1/Y)$

A - Activity of the sample in Bq/g or Bq/ml

N_a - Gross counts due to sample and background in t_1 sec

N_b - Background counts in t_2 seconds

S - Efficiency of counter

V - Volume or weight of the sample

Y - Chemical yield fraction (Y=1)

Efficiency of counter is a measure of the percentage of radiation that a given detector detects from the overall yield emitted from the source.

Efficiency (η) = $(N_a/t_1-N_b/t_2)*100/Q$

Where N_a - Gross counts due to standard in time t_1 sec

N_b - Background counts in time t_2 sec

Q - Source strength in dps (Bq)

Standard deviation is the amount of variation from calculated value of activity.

$S = 2*(N_a/t_1^2 + N_b/t_2^2)* 100/\eta*1/V*1/Y$

S is the standard deviation at 95% confidence

SAMPLE HANDLING AND PRESERVATION

1) A representative sample is collected from air filter and thyroid gland of goat, and should be large enough so that adequate aliquots can be taken to obtain the required sensitivity.

2) If samples are to be collected without preservation, they should be brought to the laboratory within 5 days, then preserved and held in the original container for a minimum of 16 hours before analysis or transfer of the samples

3) The container choice should be plastic over glass to prevent loss due to breakage during transportation and handling

INTERFERENCES:

1) Moisture absorbed by the sample residue is an interference as it obstructs counting and self-absorption characteristics. If a sample is counted in an internal proportional counter, static charge on the sample residue can cause erratic counting, thereby preventing an accurate count.

2) Non-uniformity of the sample residue in counting planchet interferes with the accuracy and precision of the method.

3) Sample density on the planchet area should not be not more than 5 mg/cm for gross alpha and not more than 10 mg/cm for gross beta.

PROCEDURE

1. For absolute gross alpha and gross beta measurement, the detectors must be calibrated to obtain the ratio of count rate to disintegration rate.

a) In Alpha counting system, Plutonium-244 (used for alpha activity in the collaborative test of this method) has higher alpha particle energy (5.49 MeV) than those emitted by the naturally occurring uranium and radium-226 radionuclides but is close to the energy of the alpha particles emitted by naturally occurring thorium-228 and radium-224. Standards should be prepared in the geometry and weight ranges to be encountered in these gross analyses

b) In Beta counting system, analytical grade potassium chloride crystals are powdered after drying at 110 degree Celsius for 1 hour and uniformly spread and fixed with gelatin or collodion in an aluminium planchet. The size of the planchet is properly chosen to match the detector and window size.

2. Dried sample residues are transferred to a stainless steel planchet

(Environmental samples from air fitters and thyroid gland of goat is used here) If the sample is to be recounted for re-verification, store it in a desiccator.

3. After calibration the planchet of air filter is placed in Alpha counting system and planchet of thyroid gland of goat is placed in Beta counting system.

4. Counts are taken and the Counts Per Minute (CPM) and activity of the sample is calculated. Efficiency of the counter is found from the counts of standard.

Deviation from standard is also calculated.

OBSERVATION

1. ALPHA COUNTING SYSTEM

SAMPLE	TIME (s)	COUNTS	CPM	NET CPM
Background	6000	7	0.07	
Std. Pu	4720	26235	333.4957	333.4257
Thyroid gland (goat)	6000	9	0.09	0.02

2. BETA COUNTING SYSTEM

SAMPLE	TIME (s)	COUNTS	CPM	NET CPM
Background	9392	2424	15.48	
Std.K-40	672	371	33.13	17.65
Air filter (in mm thickness)	7242	1894	15.69	0.21

CALCULATION

1. Estimation of ALPHA counter efficiency

Given gross counts due to standard in t1 sec (N_a) = 09

Gross counts due to background in t2 sec (N_b) = 07

$t_1 = t_2 = 6000$

Efficiency of the counter in percentage $\eta_{\alpha} = (Na/t_1 - N_b/t_2)*100/Q$

Where Q source strength in dps (bq)
where=$1.1994*10^{-3}$ dps (Given)

$\eta_{\beta} = (9/6000 - 7/6000)* 100/1.1994810^{-3}$

$= 27.79\%$

2. Estimation of BETA counter efficiency

Gross count due to standard in t1 sec (N_a) = 2424, t1 = 7242 seconds

Gross count due to background in t2 sec (N_b) = 1894, t2 = 9392 seconds

Efficiency of counter in percentage $\eta\beta = (N_a/t_1 - N_b/t_2)*100/Q$

Given Q = $1.88*10^{-2}$ $\eta_{\beta} = (1894/7242 - 2424/9392)*100/1.88*10^{-2}$

$= 18.25\%$

3. Estimation of activity of ALPHA counting system

Mass of the sample = $5.997*10^{-3}$ kg

Activity (A) = $(N_a/t1 - N_b/t2)*100/\eta_{\alpha}*1/V*1/Y$

Where Y is the chemical yield fraction = 1

A = $(9/6000-7/6000)*100/27.79*100*1/5,997*10^{-3}$ = 0.02 dps

4. Estimation of activity of BETA counting system

Mass of the sample = $9.131*10^{-3}$ kg

Activity (A) = $(N_a/t1-N_b/t2)*100/\eta_\beta*1/V*1/Y$

(A) = $(1894/7242-2424/9392)*100/18.25*1/9.131*10^{-3}$

= 15.69 dps

5. Standard deviation of the ALPHA counting system

$S = 2*(N_a/t1^2+N_b/t2^2)*100/\eta_\alpha*1/V*1/Y$

$S = 2*(9/6000^2-7/6000^2)100/27.79*100*1/5.997*10^{-3}$

= +/- 0.05

6. Standard deviation of the BETA counting system

$S = 2*(N_a/t1^2-N_b/t2^2)*100/\eta_\beta*1/V*1/Y$

$S = 2*(1894/7242^2+2424/9392^2)*100/18.25*100*10^3/9.131$

= +/- 17.34

CONCLUSION

I have observed that KKNPP is designed and engineered to the state of art of nuclear reactors in line with the current international safety requirements and principles. KK site related aspects such as seismic, tsunami, tropical storms are taken into consideration at design stage. More than 20 VVER-1000are operating in Russian Federation and in other countries. While finalizing the contract for KKNPP, additional safety features were specified which have been incorporated and their functionality is being established during commissioning. The radiological releases during the plant operation are expected to be well below prescribed limits. This fact is borne out by the experience from operating NPPs in India and abroad. Based on the national and international studies and experience, such radiological releases have no adverse effects on public health, environment and plant personnel. Safety of KKNPP was examined in relation to the TMI, Chernobyl and Fukushima accidents. It is seen that based on the advanced design safety features, safe grade level and high elevation of safety related equipment and the fact that all key operating personnel are graduate engineers who also receive intensive training, it is not conceivable that any accident of these types can take place at KKNPP.

In particular, safety of KKNPP has been thoroughly evaluated against external events of natural origin, viz., earthquakes and possible flooding of the site from cyclonic storms and tsunamis. It is seen that the seismic design of its SSCs and location of safety related components provide high level of safety against such events. Possibility of volcanic eruptions in the vicinity of the site has also been examined and no active volcanism has been identified. The magnitude of any possible tsunami that can be generated from submarine landslides in the Gulf of Mannar has been found to be much smaller than tsunamis that may get generated from the submarine active seismic faults, which has already been taken into consideration.

From the experiments carried out in ESL, I have observed that the radioactivity in the surroundings of KKNPP is well within the limits as per the regulation put forward by the government. In view of the above, we would like to conclude that the fears of the local population are unfounded and design of KKNPP meets the current safety standards.

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   C. Booklet on Kudankulam Nuclear Project – KKNPP

2. INTERVIEW WITH :

   A. Mr. Sathish A.V , health physics unit KKNPP
   B. Mr. P. Pandaram (Director of TLD dept.) KKNPP
   C. Mr. Vijaykumar, Mr. Balamurugan (ESL dept.)

3. INDUSTRY VISITED:

   A. Kudankulam Nuclear Power Plant, Kudankulam Tamil Nadu
   B. Environmental Survey Laboratory (ESL), Anuvijay Township, Kudankulam, Tamil Nadu