

**Indian Institute of Technology Madras**

**Present**

**NPTEL**

**NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING**

**NUCLEAR REACTOR AND SAFETY**

**AN INTRODUCTORY COURSE**

**Module 13 Lecture 01**

**Safety Regulation in India**

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Good morning everybody. So till now we have been talking about the different safety principles, the safety approaches that have been practiced in the nuclear power plants all over the world. As I have repeatedly mentioned the rules are common to all the countries. Thanks to the International Atomic Energy Agency which coordinates most of these activities. In today's lecture I will take you through the work being done by the regulatory authority for nuclear installations in India, that is the Atomic Energy Regulatory book. So let us see how this agency does the safety regulation in India.

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So what is the main responsibility as regards the safety of the nuclear power plants. No doubt it is resting with the

## Introduction

- The primary responsibility of ensuring safety of nuclear power plants (NPPs) rests with the organization responsible for their design, construction, commissioning and operation, i.e., the Nuclear Power Corporation of India (NPCIL). The task of laying down necessary rules and regulations and ensuring that all the safety criteria thus laid down are adequately met is entrusted to the regulatory body, i.e., the Atomic Energy Regulatory Board (AERB). This lecture describes the regulatory practices followed by AERB in meeting these objectives.

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Nuclear Power Corporation of India which is responsible for design, construction, commissioning, and operation, but then there is a agency which monitors, which guides and to ensure that the safety criteria which are laid down or being adequately met. So this is an another agency to oversee the operation of the Nuclear Power Corporation of India. So as I mentioned in this lecture we will talk about how AERB goes about its job and is there clear cut clarity for which this organization works for.

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## Atomic Energy Regulatory Board

- The Atomic Energy Regulatory Board was constituted in1983 to carry out regulatory and safety functions envisaged under the Atomic Energy Act, 1962. The regulatory authority of AERB is also derived from the rules and notifications promulgated under the Act. These include the Radiation Protection Rules (1971), Working of Mines, Minerals and Handling of Prescribed Substances Rules (1984), Safe Disposal of Radioactive Wastes Rules (1987), Control of Irradiation of Food Rules (1996) and Factories Rules (1996). Prior to the establishment of AERB, the regulatory functions were carried out by the Safety Review Committee of the Department of Atomic Energy (DAE) supported by Safety Committees for individual plants.

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So most important for any organization is what its mission, what is its goal and what it is to do. That must be very clear. If you look at the history of atomic energy in India from the time when we had the first reactor at Tarapur, of course Tarapur unit one and two were built as a turnkey project from USA General Electric USA to be particular. So nevertheless, the safety report and other things were vetted to a large extent by the Department of Atomic Energy. At that time we had a committee of experts drawn from the different atomic energy units like the Bhabha Atomic Research Center basically that was one of the most important in the initial few years. So this committee used to review the design, the operations, etc. and give decisions but as time went on by about 1983 many more plants had been set up. The Rajasthan units one and two had been set up with the Canadian assistance. When we came to the Madras atomic power station units one and two at Kalpakkam remember it was totally construction commissioning operation was by India. There is a difference between Tarapur units, Rajasthan units and Madras units. Tarapur was built the design was GE, the construction and commissioning was by GE, operation was by Indians but when we came to Rajasthan again being a new type of reactor, the unit one was again the design, construction, and commissioning was by the with the assistance of Canadians and of course the operation continued. In the unit two we took part a good amount in the construction activities and when we came to Kalpakkam MAPS units we said it is our own. We did make some design changes, little bit of design changes with respect to the Rajasthan units. So by about 80 to 83 it was felt that we must have a bigger organization to regulate the activities.

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## Atomic Energy Regulatory Board

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So the Atomic Energy Regulatory board was constituted legally in 1983. And prior to that as back as 1962 the Atomic Energy Act has been promulgated so it, the rules or the act provided what sort of rules need to be followed by the Atomic Energy establishments, one of the most important rules was the radiation protection rules. Then mines, working of mines because we have the ores, uranium ores being taken out of mine. So the mines act also was there. How to handle the different substances. Then we had the later the safe disposal of radioactive waste. Of course, some more things were added like the control of irradiation of food which started afterwards and last but not the least the factory rules, the industrial safety which needs to be followed. As I mentioned prior to setting above the AERB the safety review committee of it is known DAE-SRC was doing the regulation activities.

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## Mission of AERB

- The overall mission of AERB is to ensure that the use of ionizing radiation and nuclear energy in India does not cause undue risk to the health of workers and members of the public, and the environment. AERB fulfills its mission by stipulating and enforcing rules and regulations concerned with nuclear and radiological safety. In addition, AERB has also been given the mandate for overseeing industrial safety in all DAE units. This mandate is fulfilled by enforcing the Factories Rules.

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Now let us look at the mission. So mission statement has to be very clear. So the overall mission of the AERB is to ensure that the use of ionizing radiation and nuclear energy in India does not cause undue risk to the health of the workers and members of the public and the environment. So the occupational workers, the members of the public, and environment. So how does the AERB do this, fulfill its mission? By stipulating and enforcing the rules and regulations concerned with nuclear and radiological safety. As I mentioned it's an industrial activity so we need to follow the industrial safety in all the DEA units by enforcing the factories act.

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## AERB Powers and functions

The Atomic Energy Regulatory Board has the powers to execute various functions:

- Carrying out safety reviews of nuclear and radiation facilities under design, construction and operation.
- Issuing authorizations for siting, construction, commissioning, operation and decommissioning of nuclear and radiation installations.
- Ensuring compliance by radiation installations with the stipulated safety requirements.
- Organizing and conducting regulatory inspections of DAE units and radiation installations and enforcing corrective actions.

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So what are the powers and functions of AERB? First to carry out safety review of all nuclear and radiation facilities. And that means nuclear facility means it could be a nuclear power plant, radiation facility means it could be irradiation of sterilization of goods. It could be a gamma irradiator somewhere else for food preservation. All such units are to be reviewed by the AERB first under design, construction, and operation all phase it has to be reviewed. Then it has the powers to issue authorizations for example siting. You choose a site as we saw you require clearance from the AERB. Then construction start also you require. Then commissioning, then operation but suppose after the plant has lived its utilizable life and if you – one feels that continued operation of the plant may not be desirable, then you have to decommission it. Even at that stage you have to go and get clearance from the Atomic Energy Regulatory Board by giving how I am going to decommission it, in what way I will decommission it. Even at that stage you must not cause any radioactive release to the public, to the workers, public and the environment. So basically AERB ensures the compliance of all radiation installations of the safety requirement. Then last but not the least it organizes and conducts regulatory inspections of all nuclear and radiation establishments, and enforces corrective action. So let me recall that it has got the powers to stop any activity in case it is not rules are not being followed.

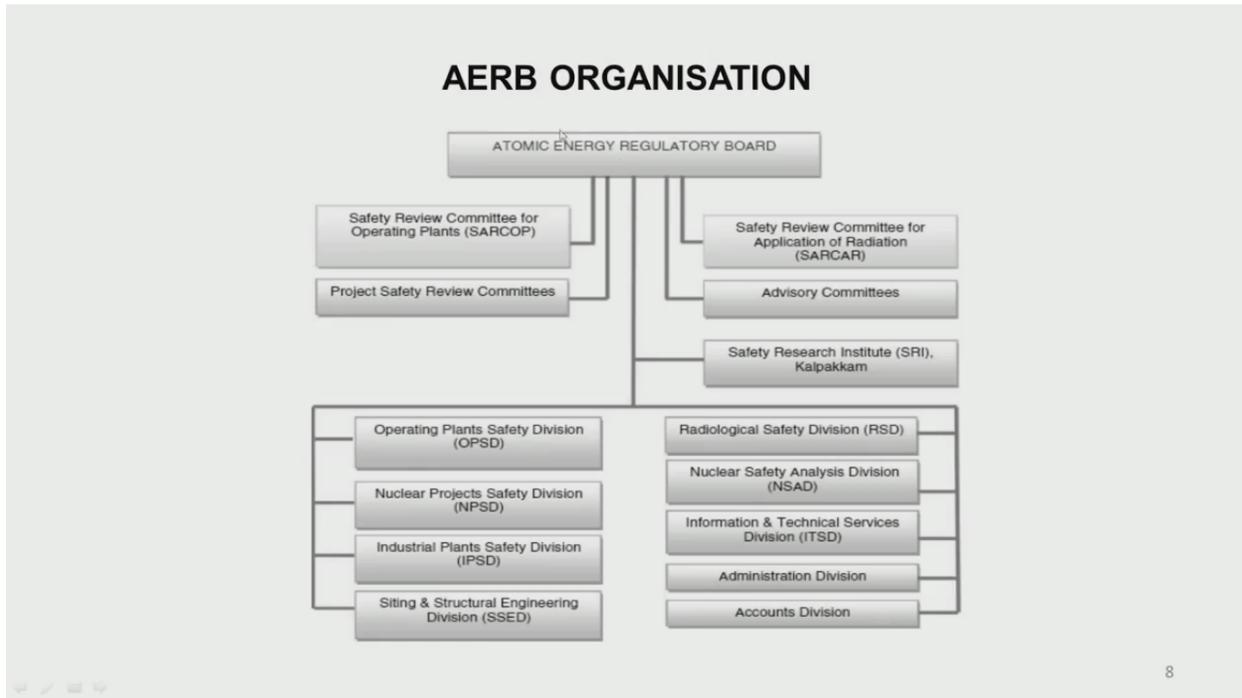
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- Assessment of radiological safety status with regard to personnel exposures and environmental radioactive releases in nuclear and radiation facilities.
- Administering the provisions of the Factories Act, 1948 in the Units of the Department of Atomic Energy.
- Reviewing the emergency preparedness plans prepared by nuclear installations and participating in emergency preparedness drills as observers.
- Developing safety documents in the form of codes, standards, guides and other safety documents essential for carrying out regulatory and safety functions.
- Funding safety research and training activities related to regulatory functions.
- Keeping the general public informed on major issues concerning nuclear, radiological and industrial safety.

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So then the assessment of the radiological safety status of the different plants as regards the personal exposures, how much are the exposures being, radiation exposure being received by the personal which are monitored at different units and also how much is getting released to the environment based on the measurements of the environmental survey labs. All these things we are being the within the powers of the AERB and should they feel that it is something has cross the limits AERB can stop the operation of the establishment. Then of course, the factories act has to be administered and it has to be followed scrupulously. Not only that in case of an emergency as we saw all organizations need to have a emergency preparedness plan; how they will deal in case of an emergency. One as regards the establishment. Next as regards the mitigation of the consequences to the occupational workers and the public and environment. So for that how – so those review the procedures and plants we shall see in depth later. Now whenever you have to carry out something there need to be a clear-cut guide or some standards so AERB has got the powers to develop the safety documents like codes, safety codes, safety standards, safety guides and all such documents which are very much essential for the user as well as AERB to carry out the regulatory and safety functions. Not only that, it tries to fund safety research because doing safety research is a big sort of cost. So wherever it feels there are issues which are not clear, it does fund safety research. Basically, in the universities of course it has got its own Institute also, the safety research institute. And last but not the least it has to keep the public informed of what it is doing and that is being done through newsletters .

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So here is the organization for the Atomic Energy Regulatory Board. This is the board which consists of members drawn out not only from the atomic energy also from outside from the research institutions and hospitals, etcetera. Then below that there are two important committees that is the safety review committee for operating plants. Other one is the safety review committee for application of radiation. So this is called SARCOP and this is called SARCAR. SARCOP is for nuclear power plants in operation and SARCAR is for radiation facilities other than the nuclear power plants. Of course, to do its function it does require the support of different committees, advisory committees are there. Now at the design stage it does require support because this comes only when you have the operation. Commercial operation starts. So you have a project safety review committee which again gives input to the regulatory board. As I mentioned it has got institute called as a safety research institute wherein it carries out research on safety aspects relevant to the nuclear and radiation facilities. Of course, whenever you have a organization you have many parts. We have the operating plants safety division. Then you have the nuclear project safety division. You have got the industrial plant safety division. Sighting and structural division. As the name says operating plant safety division looks after the operating plants. The new projects which come and the design stage they come to the nuclear project safety division. Industrial plants like the heavy water plants and the nuclear fuel corporation, etcetera. they all come under this plan. The sighting and structural engineering division is a very important one which looks into the structural safety of the different structures in nuclear power plants. This is a very important division. So it has been put as a separate activity. On the other side you also have the radiological safety division as the name implies it is responsible for radiological safety. The nuclear safety analysis division wherein AERB has got its own analysis group which does the analysis by itself, an independent analysis by itself of any of the plants. Then information and technical services division and of course the rest.

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- The AERB is supported in its work by an elaborate committee structure. The apex committees are the Safety Review Committee for Operating Plants (SARCOP), Safety Review Committee for Applications of Radiation (SARCAR) and Advisory Committees for Project Safety Review (ACPSRs). SARCOP carries out safety surveillance and enforces safety stipulations in the operating units of DAE.
- SARCAR recommends measures to enforce radiation safety in medical, industrial and research institutions, which use radiation and radioactive sources. ACPSRs recommend to AERB issuance of authorization at different stages during construction and commissioning of nuclear facilities including NPPs of the DAE, after reviewing the submissions made by the plant authorities based on the recommendations of the associated Design Safety Committees.

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So as we saw the AERB has mainly the two important thing called the SARCOP and and SARCAR. So SARCOP carries out safety surveillance and enforces these stipulations in the operating units of DAE while SARCAR does the same thing in the medical, industrial, and research institutions with major regard to the radiation and radioactive sources. Basically the source is handling of the sources, the storage of the sources, then the transportation of the sources; all these things are being done by SARCAR. Now what does the advisory committees do? The advisory committees recommend to AERB the authorizations to be given okay sighting is over. Now can I give clearance for construction. So the advisory committee will say okay now you can give clearance for construction, star off construction. So again this is not only based on that, this advisory committee will look into the output of the project, design, safety committee, and then only will recommend to the AERB to issue the license for construction. Now there is again another body called as Advisory Committee on Nuclear Safety. Now this committee is basically trying to look at the codes, standards, guides, and manuals prepared by AERB for siting, design, commissioning, quality assurance, regulation, decommissioning, etcetera. and this committee consists of all experts who weight the documents and thereby clear the documents for release so that they can be implemented in total. With the recent necessity to say that many of these codes and guides also needed for many radiation facilities, medical facilities, etc. the Atomic Energy Regulatory Board has set upon itself to translate many of these documents into Hindi and slowly they have plans to translate it into the different regional languages because your medical facilities spread all over the country.

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## Preparation of safety documents

- One of the mandates of the AERB is to develop **safety documents** that lay down requirements for meeting safety criteria for activities related to nuclear energy and provide guidance on methods for fulfilling the requirements. **Safety Codes** establish objectives and set minimum requirements that have to be fulfilled to provide adequate assurance for safety in nuclear and radiation facilities. **Safety Guides** provide guidelines and indicate methods for implementing specific requirements as prescribed in the codes, **Safety Manuals** elaborate specific aspects and contain detailed technical information and procedures.

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Now preparation of the safety documents. So what are the safety documents? They lay down the requirement for meeting a safety criteria. Then what does the safety code do? Safety codes establish objectives with regard to safety and set the minimum requirements to be fulfilled to provide assurance on safety in the nuclear facilities or radiation facilities. But then how to go about it to fulfill that is where the safety guides come. They give you some guidelines and indicate your methods by which you can implement a sudden requirement. Further down you have safety manuals which contain detailed technical information and procedures as regards achieving or implementing the safety. Now let us come to the first stage of licensing that is when the regulatory board gives, has to give clearance for the selection of the site. As we saw in about nearly two lectures on siting.

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## Siting

- Evaluation of the proposed site is carried out as per the requirements laid down in AERB's code on siting of nuclear power plants. A detailed report on site selection is prepared by NPCIL that includes all important aspects of the proposed site. These are geological, seismological and meteorological characteristics of the site, population distribution around the site, land use and water use, distance of the site from nearest public roads, airports, chemical and explosive storage points, availability of a large water body nearby, etc. The report is then evaluated by an expert committee constituted by AERB wherein all site characteristics are checked against the norms specified in the code.

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So the evaluation of the site is carried out by AERB. The report is submitted by the Nuclear Power Corporation of India on the all the aspects of the proposed site and we saw what are the siting characteristics, the seismological characteristics, the meteorological, the weather characteristics of the place and the geological characteristics all plus we said the population distribution. Then availability and use of water and nearest source of cooling water for the plant. Then how far it is located from an airport. We said it should not be very close to a airport or a chemical explosive plant. So all these data which have been provided by the Nuclear Power Corporation of India are gone through by this committee which is just constituted by AERB and then only you get the site clearance.

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Not only that it has to get clearance from the Ministry of Environment and Forests which gives the clearance after

- In addition to review by AERB, the report has also to be cleared by Ministry of Environment and Forests and statutory bodies like Central and State Pollution Control Boards. The requirement to maintain an exclusion zone inside which no residence or any other public activity is permitted has also to be met. Besides, a low population zone around the exclusion zone is also identified where only natural growth of population is permitted in order to ensure that the number of people to be managed in the event of an emergency is limited.

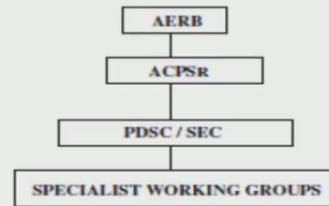
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the clearance by the Central and State Pollution Control Board because here they have a public hearing nowadays for all plants whether it is a nuclear plant or a thermal power plant and that is itself conducted under the auspices of the Pollution Control Board. We take the opinion of the public and then we take their comments. Then we give the replies and all these things together along with the other siting characteristics are given to the Ministry of Environment and Forests, which will recommend the site.

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## Design

- Towards granting clearance for start of construction, a detailed review of the plant design is conducted. For this purpose, NPCIL submits a Preliminary Safety Analysis Report (PSAR). The PSAR provides general information on plant design and details of the Design Basis of the reactor and all its auxiliary systems as also safety analysis for Normal Operation, Anticipated Operational Occurrences, Design Basis Accidents and also Beyond Design Basis Accidents. These analyses are based on a set of Postulated Initiating Events, both internal and external to the plant, as prescribed by the AERB's guides on the subject. Review of PSAR is carried out through a three-tier review process established by AERB.



**AERB: Atomic Energy Regulatory Board**  
**ACPSR: Advisory Committee for Project Safety Review**  
**PDSC: Project Design Safety Committee**  
**SEC: Site Evaluation Committee**

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Now come to design. Siting is over. Now let us come to the design. So for this what we do, the Nuclear Power Corporation of India in India which is responsible for the construction of nuclear reactors, of course. Today we have two organizations which is the Nuclear Power Corporation of India for heavy water reactors and Bharatiya Nabhikiya Vidyut Nigam, BHAVINI for the fast reactors. Both these need to submit a preliminary safety analysis report. So what does the primary safety analysis report contain? It gives a general information on the plant; how much power, how many units. Then what is the design basis of every system, every component, what are all the supporting systems, what are all the components. So to recollect the primary safety analysis report also contains the safety analysis of the plant under normal operation means everything is smooth, there is a normal operation and should there be an event what we call as anticipated operation occurrences. As we mentioned in the earlier lectures a pump trips, power fails, or a reactor trips all these. So how does a plant react to such sort of events. Then it also looks at what are all the design basis events which you are postulating, which are there for which you are going to be design is going to be safe, and also it will contain the beyond design basis events that means those events for which you may not be able to provide a design assurance but then it means that your plant, any effect which is happening can be mitigated. That is the consequences will not be reached the public and the environment. So it is a mitigation. So all these are reviewed by ARB and in fact a thorough review is done by AERB for this. Here you are the organization for this. You have individual specialist working groups which work on the different systems and then they give the report to the site evaluation committee and also to the project design safety committee and then after all that the advisory committee from project safety review after having satisfied that the safety requirements have been met will recommend to the board to issue the license so that the components manufacturer can start.

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## Consent for construction

Consent for construction authorization of projects is given in three sub-stages, called clearance stages. They are

- Start of excavation
- First pour of concrete
- Start of erection of major equipment

Each of the sub-stages has their relevant review requirements. The regulatory review process of the project is staggered and clearance for a particular sub-stage is given based on the completion of design safety review relevant to that sub-stage. This scheme has been devised to permit parallel action for detailed review while site work for construction can also proceed simultaneously.

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Okay. Now coming to the construction. Civil construction here we do not give a single clearance, we give in stages. For example, start of excavation. Now excavation is just digging out parallelly you can go ahead with some other things also. So we give first stages start of excavation. Then the first pour of concrete. Then the third is start of erection of major equipment. Why we do this? When you start the excavation you have made an assessment based on known data about the structure, about the soil, and about the rock structure everything, but when you go for actual excavation then only you will come to know where at which level the rock is, should I change the foundation now, or should I – should it be or should not. So things can change after the excavation. So the data which we get actual data we get during excavation can decide the construction methodology. So that is why we are given a part stage clearance. Then of course the first pour of concrete and why site erection we wait because this civil thing should be over in all respects, all the structures should be safe, everything should be safe then only we give the clearance for the as I mentioned this gives you parallel time for review and also site to work so that they can proceed simultaneously.

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## Commissioning

- On completion of construction, the project construction group formally hands over the plant and its systems to the commissioning group. This can be done in a progressive manner such that commissioning of items like service systems can be taken up soon after their construction is completed and construction of other reactor systems can proceed in parallel. Commissioning is the process by which constructed plant components and systems are brought into service and are tested to ensure that their performance is in conformance with the design intent. Commissioning is carried out by the plant's operations group and it provides them a good opportunity for getting thorough familiarization with the plant in addition to the knowledge acquired from class room training and study of the design and operations documents for the plant.

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Let us say all the components have been erected in place. So it signifies that the construction is over. So the plant, construction people hand over the plant to the commissioning group. The commissioning group basically consists of people who will be all operation people who will commission the plant. They have the documents from the design and the construction group. So now another agency is coming into the picture. They take over the plant. They commission each and every system and check whether all the systems are operating. So system by system, part by part of the components they will check and they do dry commissioning when the no coolant is flowing or no water is flowing or no fluid is there. They may do some dry checks of the logics. So all such things are done to see whether the equipment is operating as per the design requirements. If there is a deviation let us say some component or equipment has got damaged during the commissioning, then during the construction that will be brought to light here. They will set it right and then only go for the next step. So this, as I said, whether it is in conformance with the design intent is what is the role of the commissioning. So it is a real good opportunity also for the commissioning group, the operation personal to get familiar with all the equipments, and the knowledge acquired from this also besides this they also are given classes by the design and come by the construction people who have prepared documents for them to follow.

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Reports of commissioning of various systems are reviewed by the Project Design Safety Committee and its expert groups. Recommendations of the Project Design Safety Committee are submitted to the Advisory Committee for Project Safety Review, which then makes recommendations to the Atomic Energy Regulatory Board for consideration of granting clearances for the major sub-stages of commissioning. These sub-stages for a pressurized heavy water reactor-based NPP are:

- commissioning of the coolant and moderator system with light water,
- hot conditioning of primary heat transport system,
- initial fuel loading,
- charging heavy water to the system,
- first criticality of the reactor.

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Now each system by system after having been commissioned, it goes to the project design safety committee. This committee again sets up different groups. If suppose it deals with core, it will set up a experts group with who have a experience or operation of the core. Again these are drawn up from the different units of the atomic energy plus the regulatory board and the recommendations of the Project Design Safety Committee or you call PDSC they are submitted to the advisory committee which then is submitted to Atomic Energy Regulatory Board, recommends to the Atomic Energy Regulatory Board to enable grant the clearance. Now what are the sub stages of commissioning of a heavy water reactor plant. Why I talk about a heavy water reactor plant? Today that is a majority of plants in India of heavy water reactor. We have the commissioning of the coolant and moderator system with light water. Initially we do not put heavy water. We put light water and check the system for leaks and all operations we do that. Then hot conditioning of the primary heat transport system taking it to a higher temperature. Then we have the initial fuel loading. Then charging heavy water to the system. Then go for the criticality. So they are all sub stages have to get clearance from that AERB.

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- After first criticality and completion of reactor physics related tests, reactor power is raised in steps of 50%, 75%, 90% and 100% of full power with safety review at each stage. Thereafter the safety review responsibility is formally transferred from ACPSR to Safety Review Committee for Operating Plants (SARCOP) for continued operational safety review. Revisions, as necessary, based on commissioning results and details of as constructed plant are incorporated in PSAR to produce the Final Safety Analysis Report.

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Then after criticality we do not give clearance for a full power. We operate at low power, 50% Why? this different stages of power levels is essentially, let us look at the reactivity feedback coefficients. What I mean by reactivity feedback coefficients, in case there is a temperature increase how the reactivity, the neutronic chain reaction changes. All these effects were based on certain assumptions or data on the fuel, should there be any deviation, slight deviations we would get better data based on the actual measurements which you do on the plant. So we do at a lower power. We get these coefficients which we again analyzed to see whether they are safe. We go to higher power at 50% we stop we again look at okay I measure the reactivity coefficients and analyze my plant for 100% power. Am I safe? Go to 75, repeat the same thing like that and finally go to 100% . So safety review at each and every stage. Once this is done so the PDSC and the ACPSR their job is over now. Now the review of safety is now given to the SARCOP that is Safety Review Committee for Operating Plants which will continue the safety review, revision as necessary and all these changes or whatever you have got during the operation upto 100% commissioning are all included into the PSAR and it is called as the final safety analysis report.

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## Regulatory inspections

- In addition to detailed design safety review, regulatory inspections of the projects are also carried out by AERB teams. This is to ensure that safety requirements in construction are appropriately followed and all pre-requisites are fulfilled before going to next stage in construction or commissioning. Typically three or four such inspections are conducted in a year depending on the stage of the project. Recommendations arising from the inspections are brought to the attention of project authorities and PDSC for implementation and follow-up.

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Now let us say the clearance has been given for operation. Nevertheless, you need to keep the continued watch. So what this AERB do, they have regulatory inspections of the different projects. That is to essentially say that all the safety requirements are being followed at every stage. This inspection starts even when the plant is under construction but at that time it may be more with reference to the industrial safety aspects, and the number of inspections could be even three to four at that stage and at that stage whatever recommendations are being put they will be put to PDSC by the committees then so that the construction is smooth.

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## Project safety reviews of new designs-TAPS 3&4

- Tarapur Atomic Power Project Units-3&4 are the first Indian PHWRs of 540MWe capacity. The design of these units has been evolved by NPCIL from the standardized 220MWe PHWR over the years. The design involves several new features compared to the design of the 220MWe PHWR units. Considerable R&D efforts were also required to finalize the design of some new features. Consequently, a thorough design review is conducted for Tarapur-3 & 4. Though Project Design Safety Committee is conducting the overall safety review, several experts groups were constituted to review specific aspects of design and safety analyses.

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Now we will look at how the new plants or new designs if they come how the AERB gives license to such plants. If you recall all the present heavy water reactors of 220 megawatt electrical have been based on the Canadian designs of 220 megawatt reactors and they have evolved. Now there is enough of data available on operation of 220 megawatt electrical reactors of the heavy water reactors type. But then when the NPCIL wanted to construct the 540 megawatt electrical heavy water reactors the design got evolved through. Of course, lot of inputs from the two 220 megawatt units and then many additional features, additional safety features were built in. Not only that lot of R&D was carried out in the different units of the atomic energy and then this was evolved but nevertheless, the design review right from beginning the design review was conducted by AERB through the project design safety committee so that whatever are the deviations from the earlier ones that was looked into, wherever the modifications in the design or the design basis were thoroughly reviewed and then only this clearance for the construction of this project was given.

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## PFBR (500MWe)

- The Prototype Fast Breeder Reactor Project (PFBR) is a uranium oxide–plutonium oxide fuelled fast neutron reactor, which employs liquid sodium as coolant. Design of the PFBR has been developed by the Indira Gandhi Centre for Atomic Research (IGCAR) at Kalpakkam in the state of Tamil Nadu. The plant is under construction at the Kalpakkam Site. A Fast Breeder Test Reactor (FBTR) of 40MW thermal capacity has been in operation at IGCAR since 1985. Experience gained in the FBTR has been appropriately used in the design of the FBR.

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Now the another project which came up was the prototype fast breeder reactor at Kalpakkam. As I had mentioned earlier the fast breeder test reactor at Kalpakkam which became critical in 1985 was built with the French collaboration. Nevertheless, being the first fast reactor, the Atomic Energy Regulatory Board had done a thorough design review because in the case of a FBTR even the design responsibility was ours because we had done or carried out some changes in the design of the French to ensure better safety. For example, the French reactor Rapsodie based on which FBTR was design did not have a steam generator. It was only removing the heat through air and rejecting it to the atmosphere, but in case of a FBTR we had a steam generator. We had a turbine unit. Again this turbine was in designed and developed in India. So it was as good as a new plant and AERB did a thorough review. Just having participated in all these reviews I can tell you the safety review in the project design stage we had nearly 70 to 80 meetings each of three days to get the first step of clearance and then like that at every stage so many meetings and so many discussions were there before we got the clearance. But when prototype fast breeder reactor we design at the Indira Gandhi Center for Atomic Research, it was again a big jump from the 40 megawatt thermal to nearly 1200 megawatt thermal. We had done it based on the experience gained in FBTR.

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- This being an entirely different design concept, AERB first developed “Safety Criteria for design of the PFBR” and the guidelines given in this document are used for review of FBR design. Earlier, the conceptual design of FBR was reviewed by Novatome of France and OKBM of Russia, which are fast reactor design organizations who have considerable experience with Fast Neutron Reactors. Comments from these organizations have been appropriately taken into account in the PFBR design. Based on preliminary review by AERB, the site was accepted and clearance for excavation was given in July 2002. Considering the fact that the PFBR is the first power reactor of its kind, AERB has broadened the scope of its review work.

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But it was felt that now since we have a idea of going for large number of reactors we must draw up the safety criteria first. So the first activity which we did for the prototype fast breeder reactor was to draw up the safety criteria. Unless you have the safety criteria how you can go about the design. So AERB asked IGCAR to develop the safety criteria first and that was reviewed again in a series of meetings and not only that what we did on the recommendations of the AERB to get it reviewed, our design reviewed by some foreign agencies like the Novatome in France. Novatome is the agency for construction of fast reactors in France. And OKBM in Russia. So they have a wealth of data operation they have done. In France you had Rapsodie. Phénix and the Superphénix. Superphénix is 1200 megawatt electrical, 3000 megawatt thermal unit. All these experiences they have. So we gave them our design documents and based on their comments we have made some modifications in the PFBR design. It is very heartening to note that there were no critical comments because our design had practically taken the feedback from the operating experience of practically each and every reactor. So our design when we went to them they had little to comment. No doubt some improvements were there and we carried it out and based on that preliminary review first was the clearance for excavation. Site excavation was given in July 2002. Then being the fast reactor AERB is really going threadbare into the all these stages.

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## KUDANKULAM (2×1000MWe)

- The Kudankulam is a twin unit station of 1000MWe each based on VVER type of light water reactors of Russian Design. One of the stipulations laid down by AERB was that the design of such a plant should be licensable by the Federal Nuclear and Radiation Safety Authority of Russia. Consequently, the design has been reviewed by the regulatory body of Russia and has its approval.
- The PSAR of Kudankulam units were reviewed in AERB. Review of the chapters necessary for giving clearance for 'Excavation' and 'First Pour of Concrete' was completed initially. Further review of PSAR Chapters continued concurrently with the construction work of the project. To expedite the review process, 17 specialists groups were constituted. Recommendations of these specialists groups on specific chapters of PSAR were directly reviewed by the ACPSR.

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Then we have the other type. The pressurized water reactor from Russia which is been at built at Kudankulam and you know one of the units is already reached full power operation, commercial operation and the second unit is about to start commercial means go on power. So here we felt that AERB anyway this is a Russian safety authorities have gone into that, but nevertheless AERB reviewed the design in total by setting up large number of committees. In fact this safety review took a quite a long time and you would be surprised the safety report of the Kudankulam plant every page is authenticated, every page is authenticated by the AERB. Then after review of all that only the clearances were given at different stages. Just to give you an idea there were 17 specialist groups which worked in getting the safety clearance for Kudankulam plant. So we made changes which were as per our regulations. Wherever the Russian regulations were conservative or more safe we followed them but still we didn't, it was as per our listing. In many cases AERB had to carry out independent studies, physics studies by different experts before really confirming that yes the design is okay. So you see it is a many people say it has taken so many years yes we want to have a safe product so that minimum exposure to the working people, to the public and the environment.

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- The review methodology for Kudankulam-1 & 2 was based on the following documents:
- USNRC Regulatory Guide 1.70
- Technical Assignment for Kudankulam-1 & 2 (Design documents, PSAR/FSAR)
- OPB-88/97 (Russian regulatory documents)
- Applicable IAEA Safety Codes and Guides
- Applicable AERB Safety Codes and Guides
- Applicable Russian Safety Codes and Guides

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This just gives you some of the guides which have been followed during the review, the U.S. Nuclear Regulatory Commission guides for PWRs. You might be aware that the maximum number of reactors in the world of the PWRs and the Russian reactor called as VVER or similar in design to all these modern units. Then the IAEA codes, the Russian codes, and the AERB codes.

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- AERB and the Federal Nuclear and Radiation Safety Authority of Russia have signed an agreement for co-operation in the field of safety regulation in the peaceful uses of nuclear energy. In order to get clarifications and elaboration on certain points arising from the reviews, interaction of AERB expert review groups with Russian designers was also arranged. This was found to be very useful in getting understanding of intricacies of the design. Also, in order to ensure that methodologies followed in Russian design are comparable with those followed by other countries, inter-comparison of certain areas of design was undertaken. Similarly, verification and validation of computer codes used for design and safety analysis was also checked.

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So in this connection we have means the Atomic Energy Regulatory Board and the Nuclear Radiation Safety Agency of Russia they have collaborated and they have carried out lot of studies independently and together and they have

improved. There has been a sense of cooperation and very good exchange of information. So in case many cases we have carried out inter-comparison of design made by us and them also. Similarly the validation of the computer codes were done independently by us, even though the computer code some of them was theirs we carried out its validation independently.

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- **WE WILL SEE SOME MORE REGULATORY ACTIVITIES IN THE NEXT LECTURE**

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Now we will see some more regulatory activities in the next lecture. Thank you.

#### **Online Video Editing /Post Production**

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