Indian Institute of Technology Madras
Present

NPTEL
NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

NUCLEAR REACTOR AND SAFETY
AN INTRODUCTORY COURSE
Module 07 Lecture 02
Other Events

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Good afternoon, everybody. We shall continue our morning's lecture on events in the different nuclear power plants and establishments which are a very valuable source of input for us to decide the different design basis events for a nuclear plant. We discussed the important accidents like the Chernobyl, the Three Mile Island, the Fukushima.

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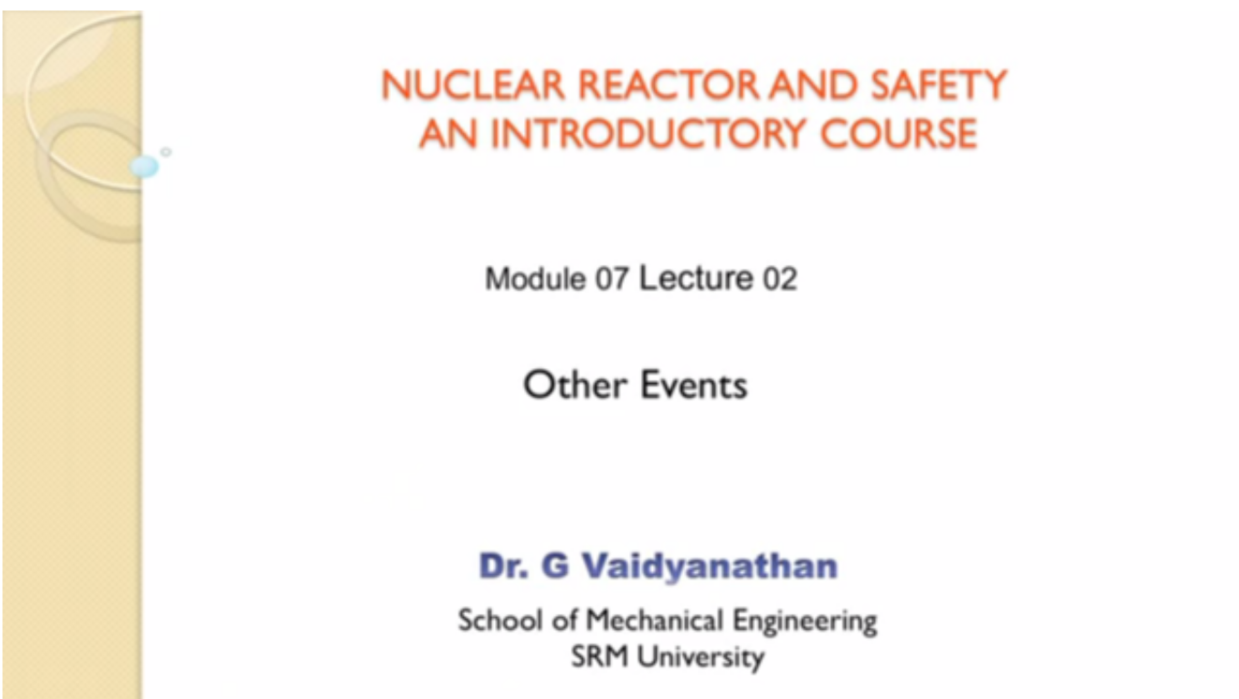

And some more and some more events of a different type you can -- we'll just go through that.

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KYSHTYM ACCIDENT

- The Kyshtym accident (Urals, USSR) happened in 1957 in a radiochemical plant for the recovery of plutonium. One of the three tanks of highly radioactive liquid waste was left without cooling and its instrumentation was defective. Overheating up to 380°C resulted together with the blast of an equivalent to 10 t of TNT which caused the tank to burst almost Lifting the upper concrete shield, weighing **160 t. $740*10^{15}$ Bq of activity were released and 10000 people in an area of more than 20000 Km²** were evacuated. The operators succeeded in running far from the plant, alarmed by the heat emanating from the tank and there were no casualties.

Here this accent happened in USSR in 1957. It is called the Kyshtym accident. There was a reprocessing plant for recovery of plutonium, and one of the tanks containing this liquid radioactive liquid was not having the cooling and instrumentation was also defective. So because of the decay heat produced, the temperature started rising. The temperature rise to about 380 degree centigrade and the whole thing had a blast, nearly equivalent to 10 tons of TNT, and you can see the how much of radioactivity because it was all reprocessing and everything was in a concentrated area. So it is a very large amount of activity release. Of course, operators didn't get much exposure, but then it was a real serious accident.

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VANDELLOS

- The fire at the Vandellos 1 station in Spain in 1989 was an incident rich in lessons to be learnt on the ways to effectively fight fires (typical common cause of failure in nuclear plants). A sequence of events was started by a fracture in a turbine blade. Strong vibration of the turbine generator system followed together with a fire of the turbine lubrication oil and of the alternator hydrogen coolant. The fire spread generating many types of subsequent faults, including an internal station flood. The personnel succeeded in maintaining the operation of the minimum number of components necessary to cool the (gas-graphite, UK-type) reactor. No external radioactivity releases took place. Many lessons were learnt about fire aspects of design of power stations.

Here is another incident, which happened in Vandellos, Spain. This is about a fire. The whole event started with fracture of a turbine blade and the fracture of a turbine blade, it broke, and once it broke inside and with the high speed, it really created a spark that resulted in a fire in the lubrication oil system and first, the balancing of the whole turbine got disturbed. The lubrication oil failed. This fire came out. It got into the alternator hydrogen cooling circuit and subsequently, the fire, it started -- complete the station, whole place, the fire went.

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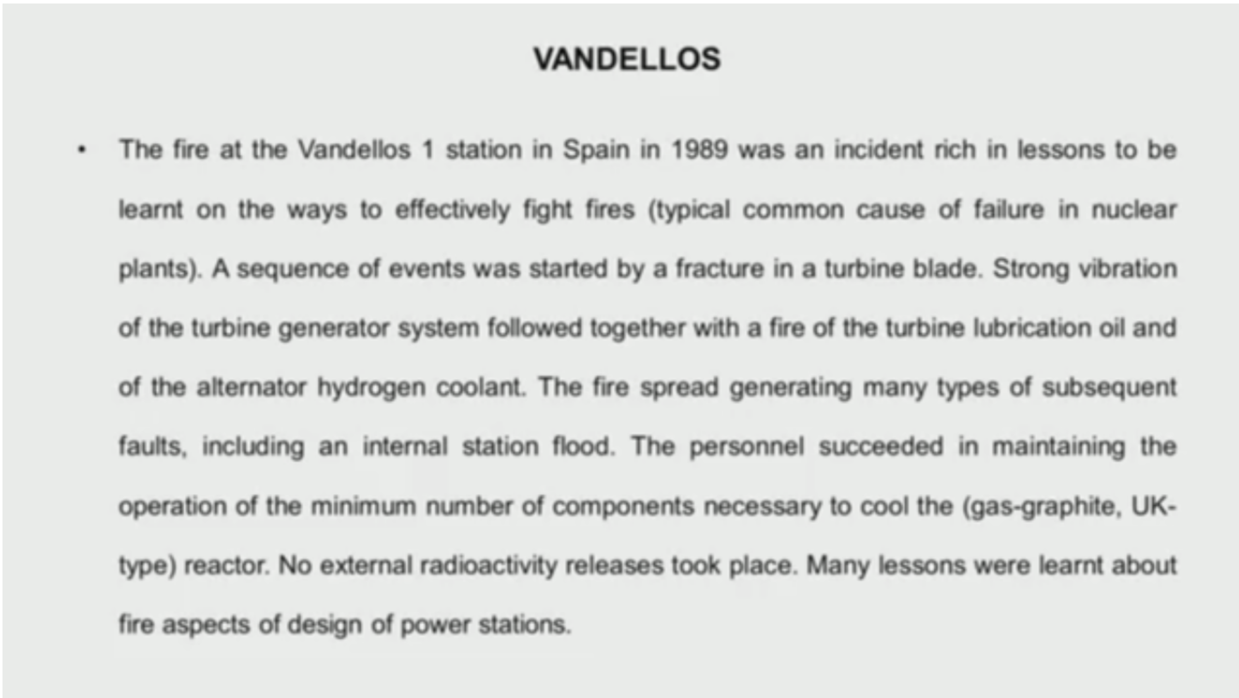

Finally, it appears there was a flooding of the station. Maybe some pipe had got ruptured. No doubt the personnel were able to maintain the situation. There was no external release, but then lessons were learnt about the fire aspects. In fact, if you look up later the Narora fire also had something like it started with the fracture of a turbine blade.

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CRITICALITY ACCIDENT AT TOKAIMURA

- 1999- The accident happened when highly concentrated (U235 18.8%) uranium used for the fast breeder experimental reactor "Joyo" was manufactured temporally using facilities for low concentrated uranium (U235 3-5%). JCO was concentrating uranium fuel, which is a part of the fuel fabrication process. they injected a uranyl nitrate solution, including uranium that was over critical mass into the precipitation drum that was originally designed for the different purpose and was not designed in the shape that is required for criticality safety". The critical state continued for several hours without stopping immediately. The countermeasures for closing the critical state were examined, and it was decided that the water in the precipitation drum jacket that caused the critical state should be drawn off.

Tokaimura accident is really an unfortunate accident wherein this plant is actually meant for making fuel for the light water reactors wherein you deal with enriched uranium of about 3 to 5%. However, with Japan having a fast reactor program, they wanted to prepare the fuel of a high enrichment, nearly about 18 to 20% Uranium-235, and they thought why not we use the facility at Tokaimura itself. So they were concentrating the fuel and they had a Uranium nitrate solution which was in a vessel. That vessel was normally being used for 3 to 5% Uranium-235.

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One thing we must remember that for any critical -- critical reaction, that is a chain reaction to have, there is a critical geometry. The fuel placed in a particular geometry can become critical. That is what we saw natural reactors existed in the Gabon in South Africa. 17 reactors existed in the nature. That means the geometry was such. So whenever we look at the design, we see that the geometry should be such to make it critical, but in a situation like this like a accident, we must -- we can't change things. The geometry will remain. So here this geometry which was meant for 3 to 5% of Uranium 235 enrichment was not the right one for 18 to 20% enrichment.

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So what happened? It became critical and they couldn't do anything. They thought perhaps there was a water at the bottom which might have made the criticality and tried to take it off.

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- This is very dangerous work, because it is necessary to approach the precipitation drum in which radiation leaked. Volunteer employees of JCO worked under the threat of death, and the critical state stopped at last after having continued for nearly 20 hours. The concentration operation was contract work and moreover the work was complicated. Essential safety countermeasures were ignored, and the company allowed too thoughtlessly illegal work methods, which resulted in the occurrence of the accident. The problems were that not only the occurrence of the accident but also a lack of prior preparation for countermeasures in the event of a criticality accident and concrete operation procedures had not been checked by the government. A total of 119 people received a radiation dose over 1 mSv from the accident. Three operators, suffered radiation burns andtwo of whom died later
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But then that also without proper precautions and finally, it took 20 hours for them to stop the reaction, but in the meantime, people got -- three operators got radiation burns and two of them died later. Here, basically, two things. First, the fuel fabrication that liquid in that vessel should not have been done because it was a geometry which became critical. So the first mistake, and there were no procedures, written procedures made.

And another thing was in the case when the fellow went to take out the water from the vessel, he had not taken the clearance or work permit properly and just did it in the huff of the moment. So this really an accident would not have happened had there has been enough thought and proper procedures made and clearances -- clearances obtained from the regulatory authority. This is very important. In our country every procedure, unless it is cleared by the regulatory authority, we won't. If there is no procedure, we won't do the job. I don't know how in Japan this was done.

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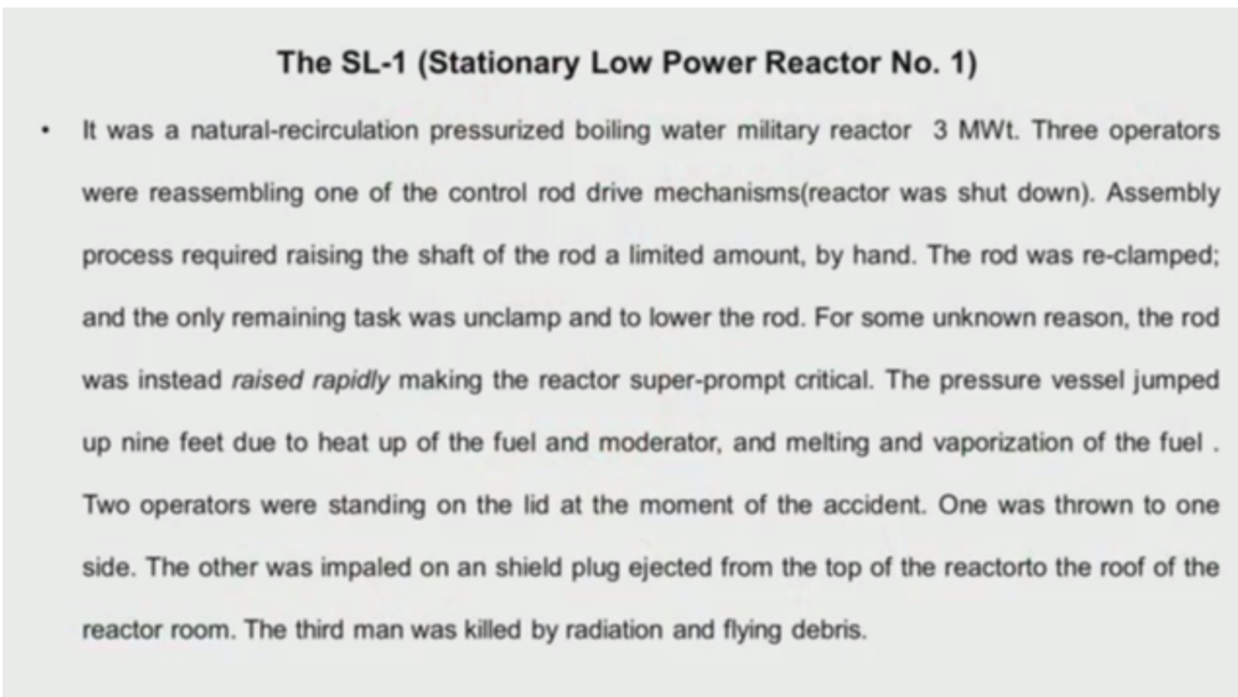

The SL-1 (Stationary Low Power Reactor No. 1)

- It was a natural-recirculation pressurized boiling water military reactor 3 MWt. Three operators were reassembling one of the control rod drive mechanisms(reactor was shut down). Assembly process required raising the shaft of the rod a limited amount, by hand. The rod was re-clamped; and the only remaining task was unclamp and to lower the rod. For some unknown reason, the rod was instead *raised rapidly* making the reactor super-prompt critical. The pressure vessel jumped up nine feet due to heat up of the fuel and moderator, and melting and vaporization of the fuel . Two operators were standing on the lid at the moment of the accident. One was thrown to one side. The other was impaled on an shield plug ejected from the top of the reactorto the roof of the reactor room. The third man was killed by radiation and flying debris.

Then this goes to a very old -- it was a military reactor in earlier days where it was not very, very, you know, very well instrumented and you know there were no computers in those days. So it was a natural circulation boiling water reactor and the operators were assembling a control rod system and because of the assembly when they are doing, one of the rods had to be raised a little bit amount. So the rod was raised and then rod was clamped.

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Then other one was to unclamp the -- next step, unclamp the rod, put it down, but for some unknown reason, instead of putting it down, it was taken out continuously, and the reactor became prompt critical, what you say on prompt neutron itself became critical and the pressure, the power increased, so the water started boiling, the pressure increased, so the pressure vessel it appears went up by about nine feet. Fuel melted and operators who were standing on the lid, one was thrown to the side. Other fellow was just pushed up and he was hanging at the top, and the third one was killed by the radiation and the flying debris.

So this was a real event. So, of course, nowadays none, no, none of the reactors have such things because nothing is done manually. Everything is done automatically and there are lot of checks. This is to tell that such a thing can happen. So in all reactors we have inadvertent raising of a control rod is one of the events so for which we designed the plant, the response of the plant such that the reactor will trip automatically based on many signals, so such an event is not possible today.

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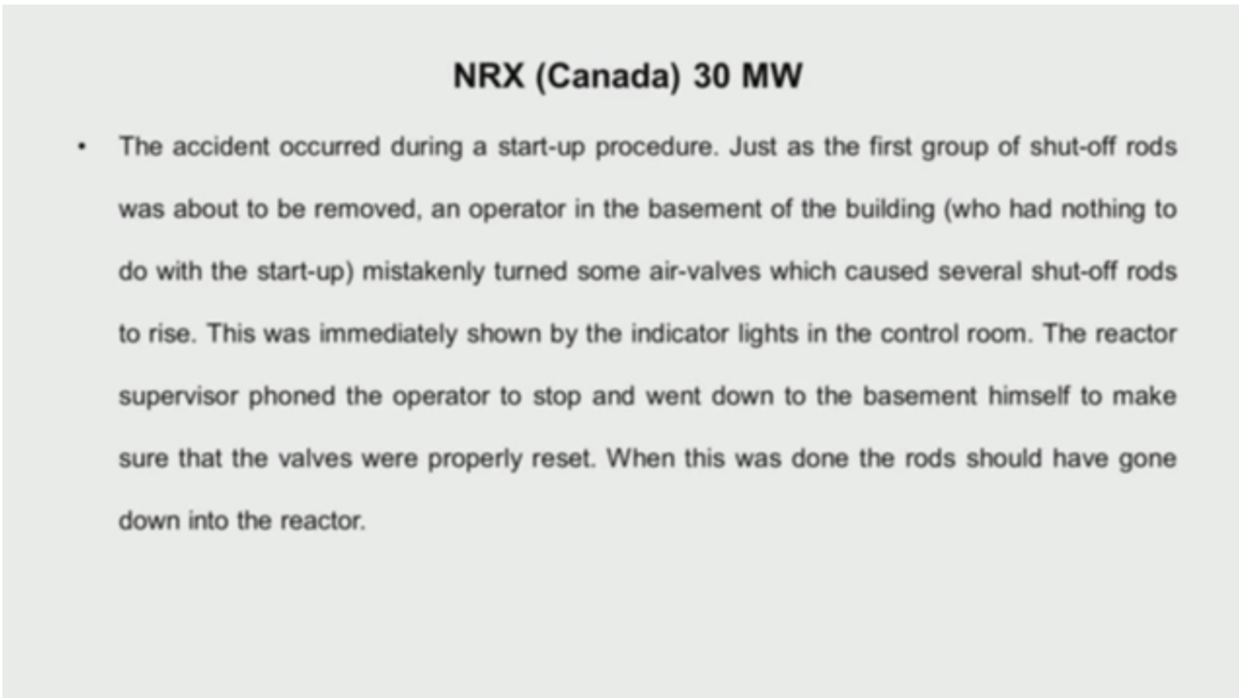

Then the NRX reactor in Canada. Again, here again, it was some manual instructions being given. When the shut-off rods were to be removed, they resulted actually in rising of the shut-off rods and there was a over power and fuel melting. So here again, it is a similar even. Again, as I mentioned such events are not possible today.

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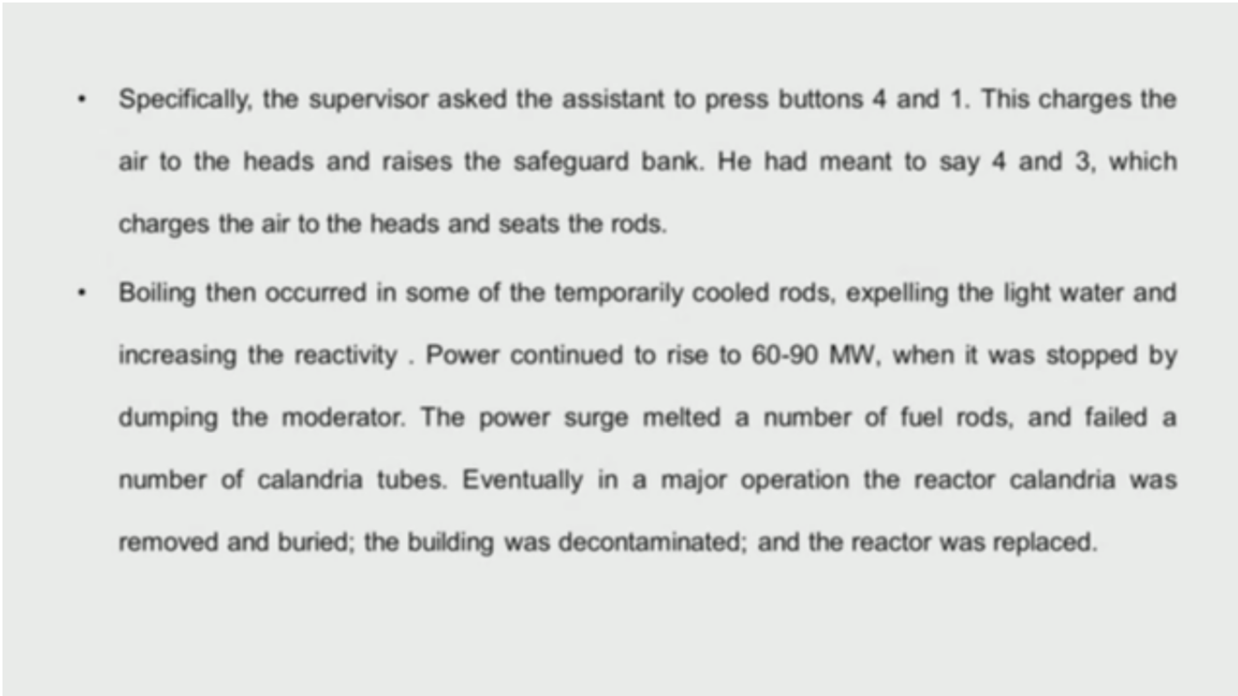

Here the major thing was the communication. You say open this valve. He wanted to say valve four and three you open so that the control rods will come down. He told that fellow heard it as four and one. That's all. So this shows that communications are very important and it is even important today also.

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Davis-Besse Reactor Pressure Vessel Head Degradation

- The licensee found that three CRDM nozzles had indications of through-wall axial cracking (nozzles 1, 2, and 3, which are located near the top of the RPV head). The licensee investigated the condition of the RPV head surrounding CRDM nozzle 3. The investigation included removing the CRDM nozzle and removing boric acid deposits from the top of the RPV head. Upon completing the boric acid removal on March 7, 2002, the licensee conducted a visual examination of the area and identified a large cavity in the RPV head on the downhill side of CRDM nozzle. The corrosion was caused by borated water that leaked from the reactor coolant system onto the vessel head through cracks in the nozzle and the weld that attached nozzle 3 to the RPV head .

Then the Davis-Besse reactor pressure vessel. Here the top of the reactor pressure vessel houses the control rod dry mechanisms and during one of the investigations, operator found that near a CRDM nozzle, some Boric acid deposits were there. You know, this Boric acid is used as a neutron absorber in the plant. So he was wondering from where this Boric acid would have come. So he visually tried to examine that area and then he found a cavity down side of the nozzle.

Apparently, that corrosion which had taken place was by the borated water that had leaked out from the reactor coolant and it was good that it was noticed. Otherwise, there could have been corrosion could have really damaged the control rod dry mechanism area and it could have prevented the control rods from falling into the core when required. It is a very good, you know, inspection surveillance which showed. So, in fact, subsequent to this all pressurized water reactors, all reactors top or examine heads were examined and luckily not much -- nothing much was there.

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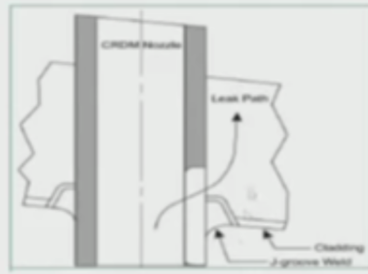
- The remaining thickness of the RPV head in the wastage area was found to be approximately 3/8 inch. This thickness consisted of the thickness of the stainless steel cladding on the inside surface of the RPV head, which is nominally 3/8 inch thick. The stainless steel cladding is resistant to corrosion by boric acid, but it is not intended to provide structural integrity to the vessel. Failure of the stainless steel cladding would have resulted in a loss-of-coolant accident (LOCA). The LOCA would have resulted in actuation of the plant's emergency systems.



So, basically, if you see, there was a leakage. This is the nozzle in which the control rod dry mechanism goes. There was a leakage path and slowly it had come out and corroded this material. So the stainless steel cladding is, of course, resistant to corrosion, but this sort of cladding is not sufficient to provide any structural integrity. So in case if it had come so far, it is possible that it could have failed and CRDM may not have been able to pass through the -- to the core when required and there could have been a loss of coolant accident also. All the coolant would have gone like this. So many things were escaped because of this surveillance.

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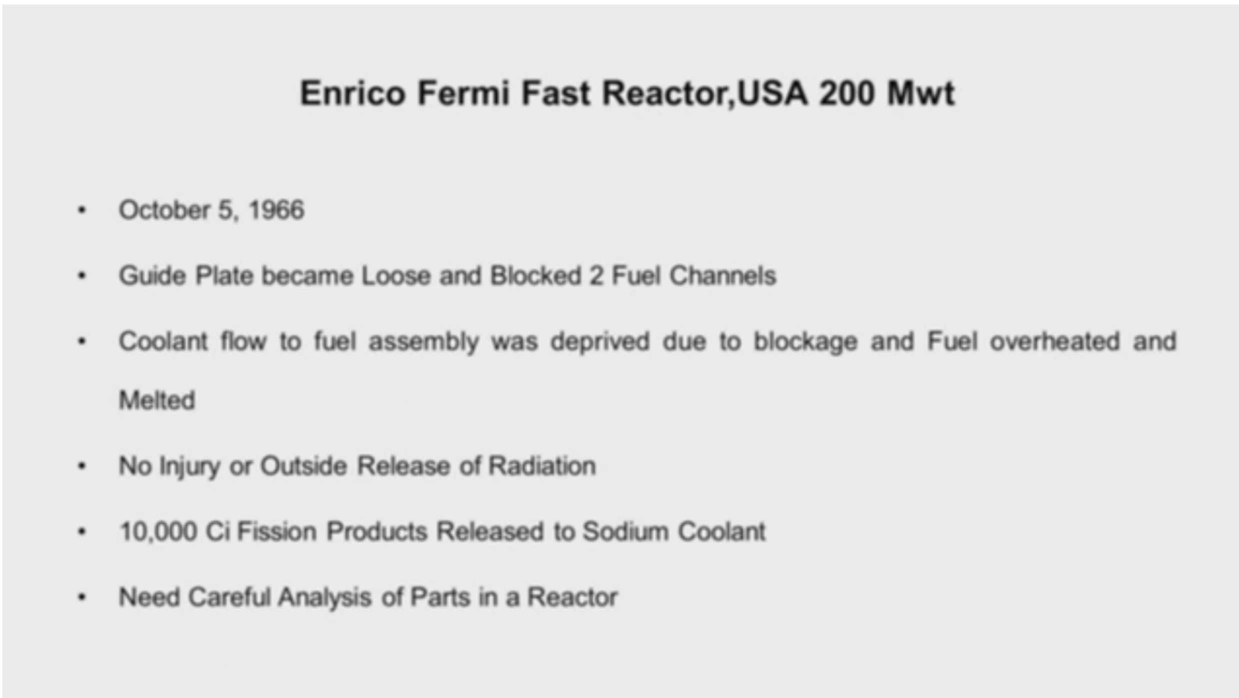

Then Enrico Fermi Fast Reactor -- reactor in 1966. Again, I am talking to you when no computers, not very good what you call instrumentation. The plant had started and then operating. During one of the shifts, the operator found that the power had gone down slightly. So he adjusted the power. Next shift, again, the power had gone down. It was a small amount. It was adjusted, but nobody put their thought, "Hey, why this power has gone down? Is there some negative reactivity contribution coming in from somewhere?" So it went on and on.

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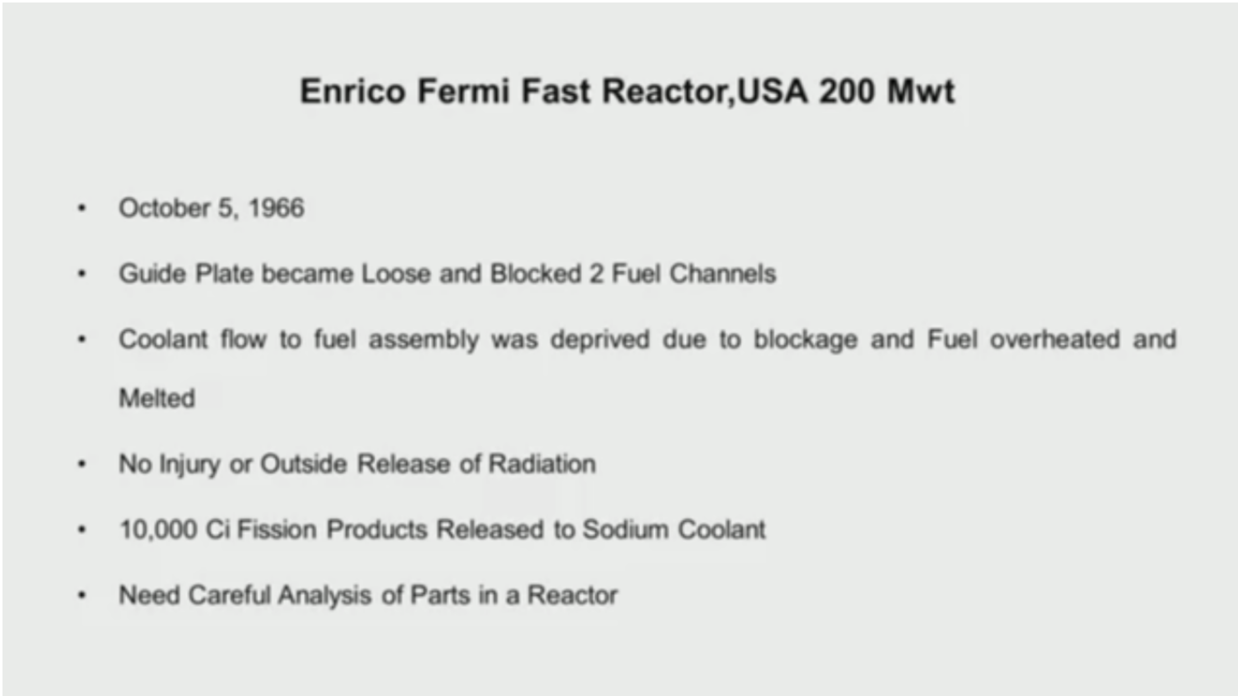

Finally, activity was there in the cover gas circuit because it's a Sodium called fast reactor and then apparently, what has happened? Some plate, which is supposed to be a part of the core catcher, was made of Zirconium. This was installed towards the end of the plant after a review by the safety authorities, but that plate had -- one of the plates had gone loose and come out and closed the flow to the one fuel assembly, so one fuel assembly was deprived of the flow. So the temperatures increased because coolant was not flowing. Fuel overheated and melted.

So, because it was one assembly, there was not much change in the reactivity, slight negative reactivity, it happened. So the operator never knew. Of course, the sodium got contaminated because of the failure. No injury or no release of radiation, but this incident I can tell you has been a very, very eye opener for the fast reactors. Today, the entry to the fuel assembly is not through a single hole. It is through multiple entry holes so that even at the worst circumstance, the total blockage of a assembly is ruled out. That's a thing which we have learnt.

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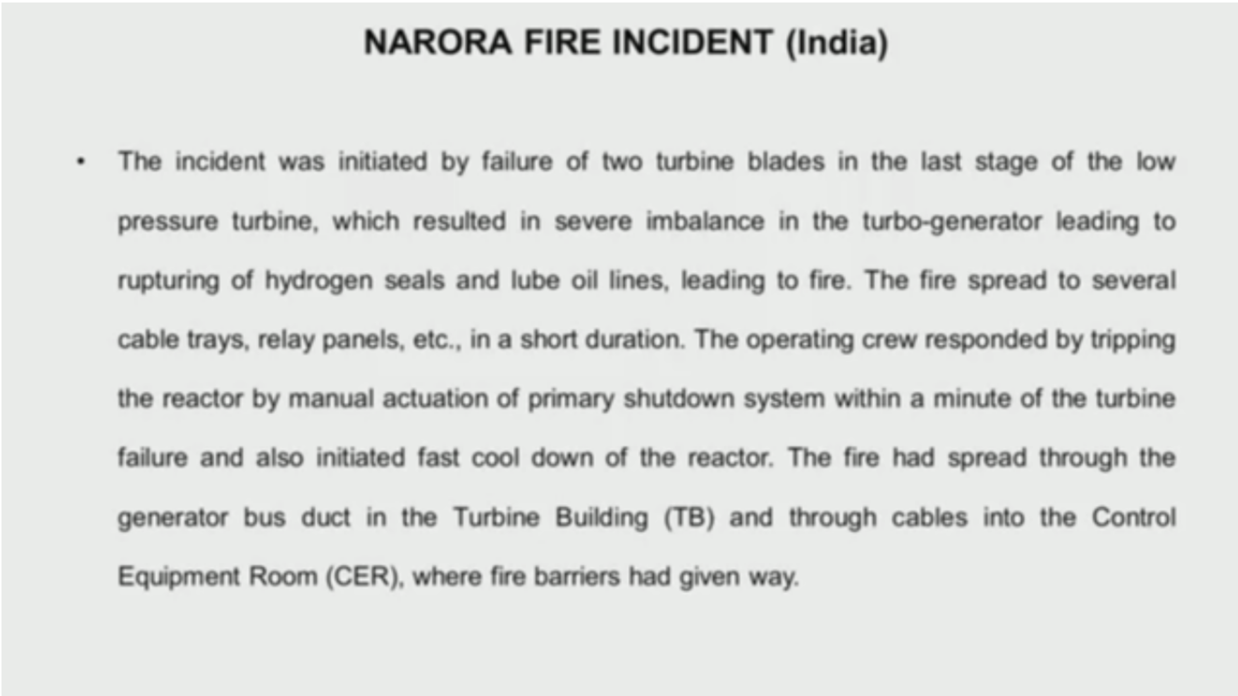

The Narora fire accident, very important. There was a failure of two turbine blades of the low-pressure turbine and this resulted in an imbalance. They are very nicely balanced. Turbine generators will be balanced well. So once the balancing went off, it ruptured the seals of the generator wherein because generator and turbine are on the same shaft. So once this shaft is imbalanced, it also affects the other shaft, and the hydrogen seal broke, and hydrogen came and this turbine blade, you know, hitting the casing produced a spark. The hydrogen caught this spark. Then the fire went from the generator to the cable trays to the relay panels and in fact control room was having smoke.

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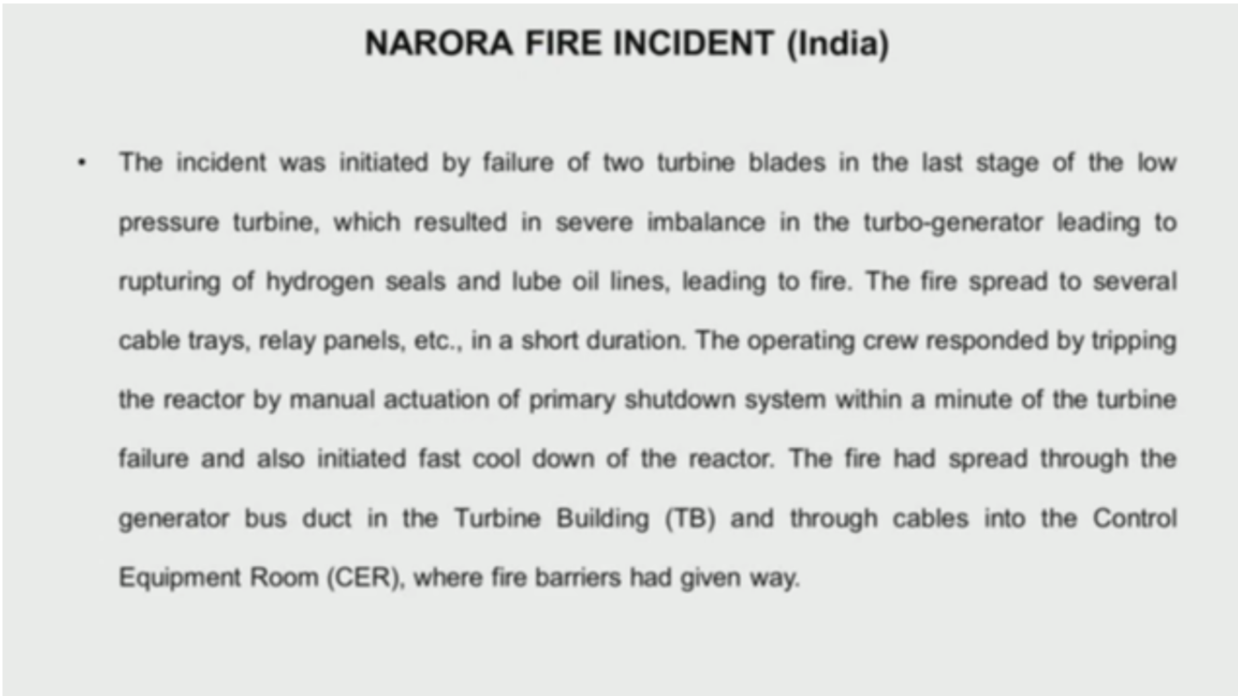

The operation people, they tripped the reactor within minutes of the turbine failing and put the reactor on fast cooling, but the fire had spread through the generator bus duct to the control room and these barriers had given way.

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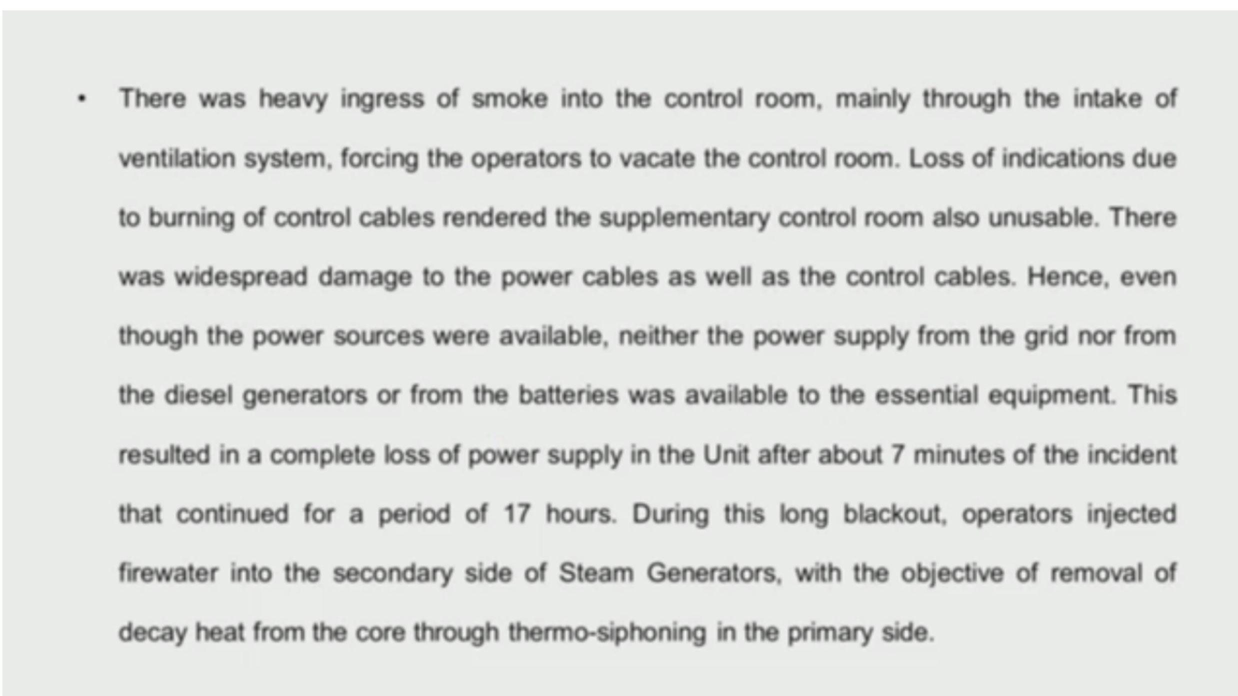

As I mentioned there was heavy smoke in the control room. Then some of the control cables had been burnt. So even they could not be operated from the supplementary control room. So power source is available. Diesel generator power is available, but we are not able to provide the power to the equipment. So, effectively, this resulted in a loss of power supply and this continued for nearly 17 hours. Of course, we have in our procedures different types of cooling. We have diesel operated fire water pumps, which could be used as the last stage of cooling and the operators use that, and cool the core and no activity came out. There was no fuel failure.

But here we learnt one thing that the all the cables going to the reactor building were in a single path. Normally, when we say in the defense in depth principles, redundancy, diversity and independence, independence of the path so that common cause failure should not be there. So they had taken care everywhere, but just at the -- normally, people don't like to have too many penetrations in the reactor building because it will affect the leak tightness and leak tightness is important so that activity does not come out.

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- There was no radiological impact of the incident. The major fire was put out in about 90 minutes. The event was rated in the INES scale at level-3, mainly on account of the degradation of defence- in-depth of engineered safety features during the incident. Investigations into the NAPS fire indicated that certain recommendations made during the design reviews, particularly with respect to cable routing, were not fully implemented at NAPS. This observation, led AERB to take steps to strengthen the quality assurance organizations in the NPPs and to establish a special group in AERB, the Directorate of Regulatory Inspection and Enforcement (DRI&E), to carry out regulatory inspection and audit of the NPPs and other facilities on a regular and periodic manner.

So here was a lesson learnt that we should know how to make better independent routings of cable to remove the common cause failure. Everywhere nowhere else there is a common. This was the area where it happened. So, of course, this led us to, you know, many changes.

One of the important changes was the regulatory board set up a separate inspect -- Directorate of Regulatory Inspection and Enforcement. Remember inspection and enforcement. This Directorate, what it does? Every year it goes to all the facilities, goes through complete records, both automatic records, manual records, what are the recommendations of the internal safety committee, outside safety committee, AERB, and sees whether they are all implemented. Many times there might be a recommendation but not implemented. So this puts a important restriction that no establishment can just have a, you know, recommendation but not implemented. This is very, very important and this has been extended to not only the nuclear facilities, but all the related auxiliary facilities also.

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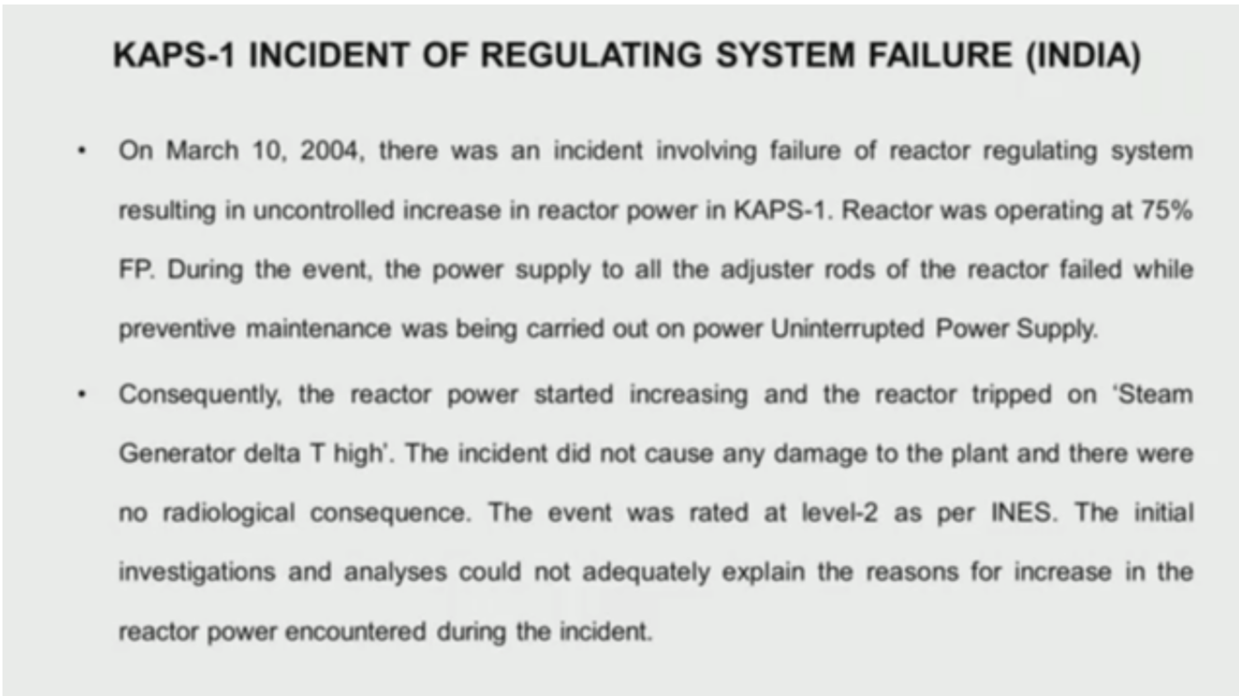

Then we did have an incident of a regulating rod failure in 2004 in the KAPS-1 plant, heavy water reactor. Reactor was operating at about 75% power and power supply to the adjuster rods failed when preventive maintenance was being carried out on the UPS system, UPS is uninterrupted power supply system.

Now what happened? There was an increase in the reactor power and the reactor tripped because the temperature difference across the steam generator went high. So there was no problem, no radiological consequence, but investigations needed to be done, why the power went up?

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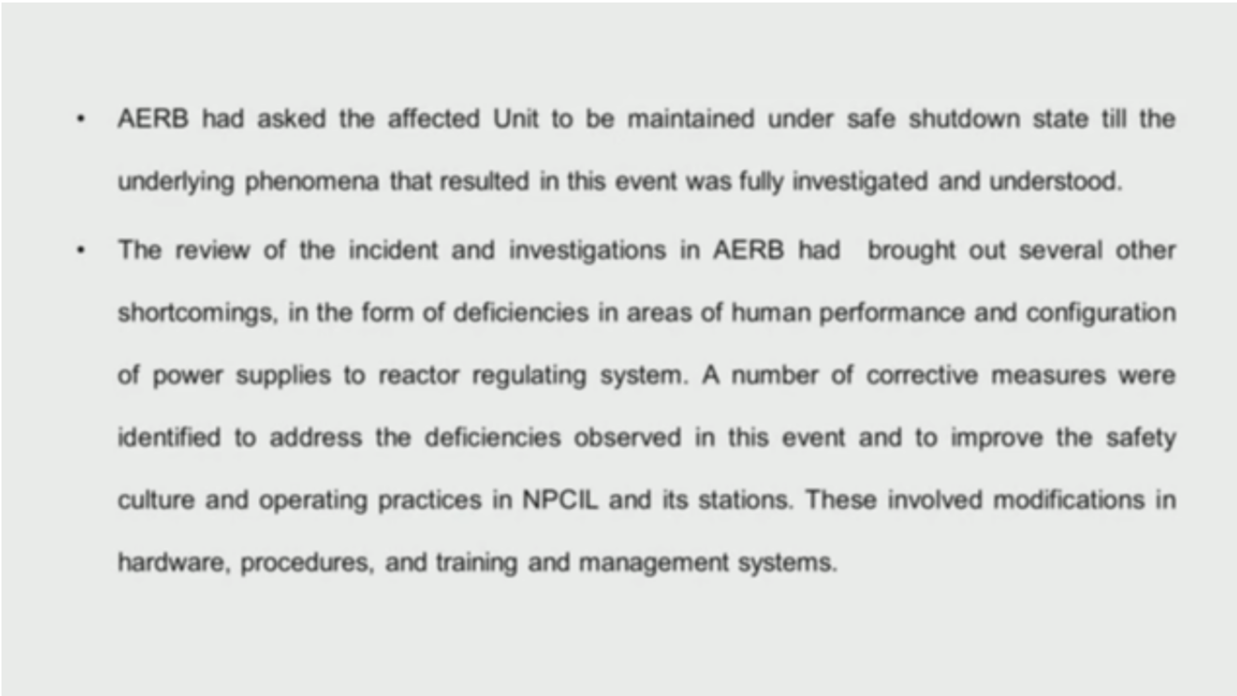

So we understood once the whole thing was analyzed that apparently, the fuel composition of the core in certain areas were different than what had been thought in the design and that had not been taken into account in the analysis. This was a minor event, but nevertheless the reactor was restarted only after understanding the whole thing and again, the question of the power supplies failure, you know, UPS we say uninterrupted power supply system, but it got interrupted. How? So the design was strengthened so that the -- there is no loss of uninterrupted power supply.

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Browns Ferry Fire, USA (March 22, 1975)

- Electricians were trying to seal air leaks in the cable spreading room, where the electrical cables are separated and routed to the reactor buildings. They used strips of spongy foam rubber to seal the leaks and were using candle flame to determine whether the leaks had been successfully plugged -- by observing how the flame was affected by escaping air. The Technician put the candle too close to the foam rubber, and it burst into flame and the fire slowly propagated through the burning of the cable insulation and spread into the reactor building. The resulting fire disabled a large number of engineered safety systems at the plant, including the entire emergency core cooling system (ECCS), and had a potential to result in a core meltdown accident, demonstrates the vulnerability of nuclear plants to fire.

Then coming to a fire event, now fire is one of the important events. See how all the reactors as I mentioned have a containment and we check the leakage through the containment. That is we want that atmosphere inside the air. Air inside the reactor building should not go out. So we do do a check normally annually to see whether there is any leakage. So we slightly pressurize the outside air that is inside air we try to take it a little bit low outside through any penetration. Then we look whether air is coming out or not.

And here in the Browns Ferry Power Plant, they put a candle very close to the, you know, routings where the cables are entering into the reactor building. So if the flame shifts in whichever direction shifts, they know the air flow is happening in that direction, but they had taken it, they were keeping on doing, and they took it very close to the place where the insulation of the cable was there and the cable insulation got fired. Cable insulation got fire.

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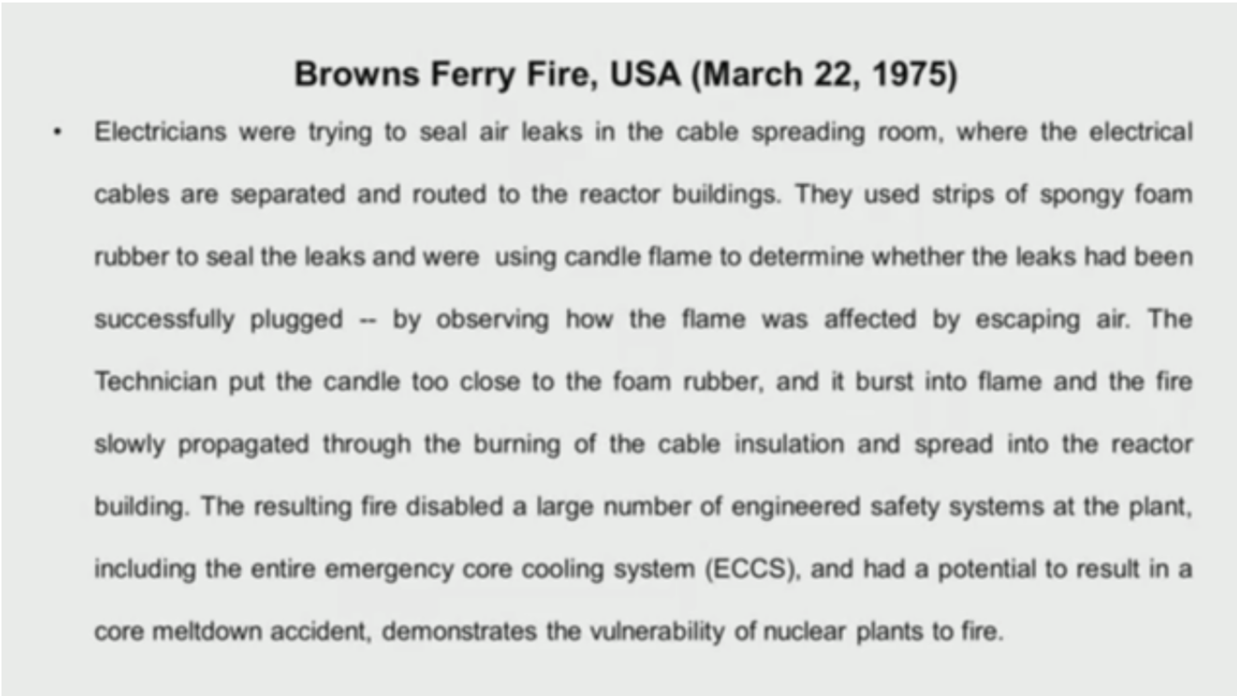

It spread throughout the reactor building and lot of safety systems were affected including the emergency cooling system, but this showed the plant was, of course, in a apparently in a not -- not in an operating state. So this was not a very big problem, but how did happened? So this really showed that in case you want to do testing, don't take a fire. Do by some other means. In many cases, we do -- we actually take an incense stick wherein we just small smoke. The smoke, which direction it goes, we check.

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Rajasthan Atomic Power Station –2 (July 25,1985)

- The 200Mwe unit was operating at rated power when one Primary Coolant Pump (PCP) tripped on Instantaneous Over current, followed by Reactor trip. Attempt was made to restart the pump but the pump did not start. Afterwards, three more PCPs tripped. Fire broke out in the boiler room of reactor building. Fast cool down of the reactor was initiated. Locating the fire source was not possible due to dense smoke. It took some hours before the smoke could be cleared. The cause of fire was due to overheating of a straight-through cable joint.(Cable joints are not permitted in HT (>3 Kv) power cables). The attempt to restart the pump after an over current trip had pumped in a lot of energy to the joint to increase its temperature resulting in the initiation of fire.

Again, coming to one more Indian power plant was the Rajasthan Atomic Power Station Unit 2. Of course, it was one of the oldest units built with Kennedy, built of the Canadian design. So it was operating at the rated power and one primary coolant pump, heavy water pump tripped on over current. Then, apparently, the operator wanted to start the pump. It didn't. Then he found that slowly one by one pump, three more pumps tripped, and then there was a fire in the boiler room of the reactor building. So the operator immediately ordered a fast cooling of the plant because the primary coolant pumps are not available. Then everything was brought to a, you know, very normal state. Then when they investigated, the cause of the fire was overheating of a cable joint in the boiler room.

Now as a feature we don't allow cable joints where the voltage is greater than 3Kv inside any of these should not be within the building, but somehow this was overlooked, and every time you start the pump, there is a overcurrent, starting current is higher than the normal current that has pumped enough energy into the joint, it failed and there was a fire. So this is again, nothing happened, but a lesson learned.

Let us move on to we have seen the pressurized water reactor. We saw the Enrico Fermi fast breeder reactor. We saw the boiling water reactor at Fukushima and Chernobyl. Then the Monju reactor in 1995 is a very, very unfortunate event.

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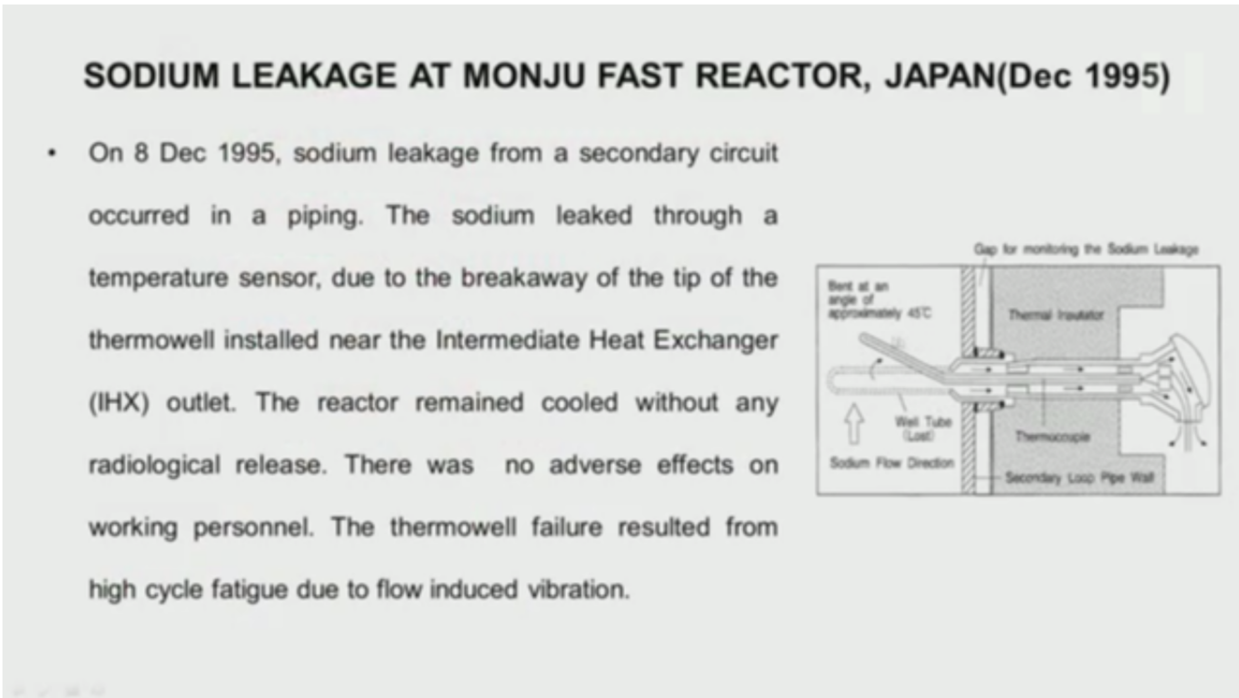

You have in the secondary sodium system a thermowell, which measures with a thermocouple inside, which measures the temperature of sodium. The sodium flow is happening in this direction and apparently, this had got broken. This weld had failed and sodium started coming out through this head of the thermowell and then it came out to the outside, outside the insulation and the wall, pipe wall and started burning.

So as such nothing happened to the primary sodium system. The secondary sodium leaks. There was no adverse effect on the working personnel also. That sodium leakage was high before the really operators decided to dump the sodium into the storage tank. That is a normal step.

Unfortunately, the operators took a long time to do that, but mind you such incidents can show that the training of the operators is a very, very important issue, licensing of the operators. So we do train the operators. We have checklists for them every year so that, of course, there is an incentive whenever they complete a checklist, we give them a bonus. So there is a thing event and we need to do this continuously without any stop.

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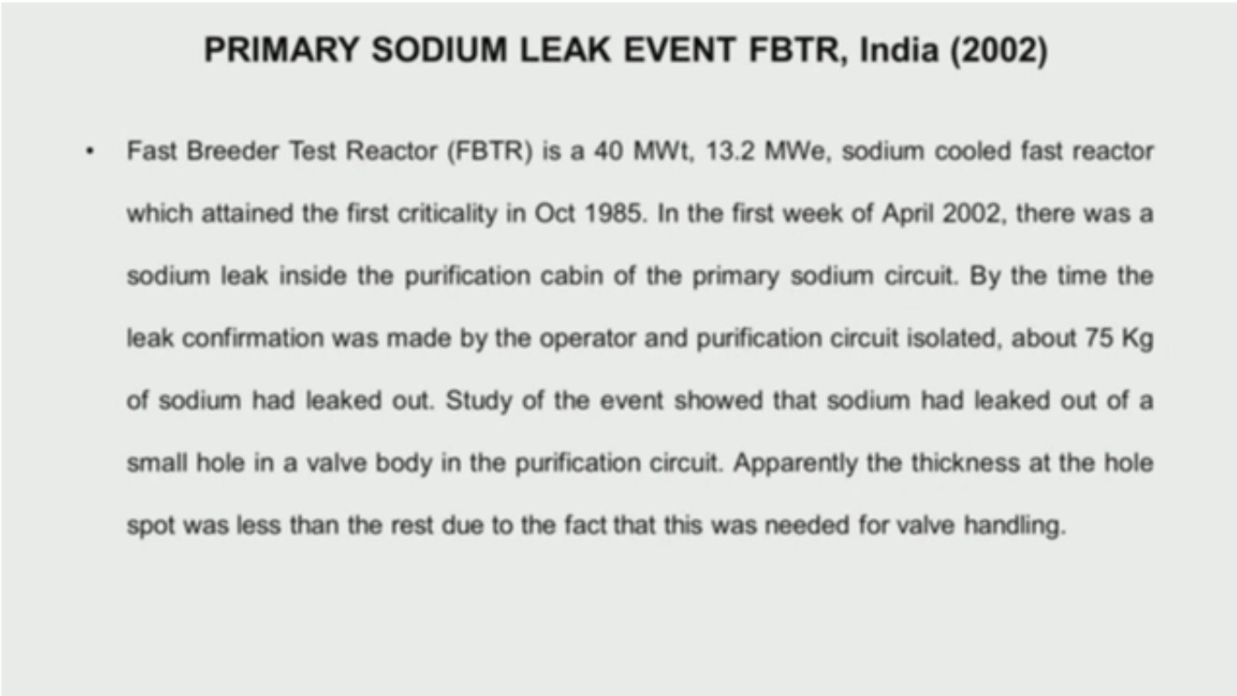

Then coming to the Fast Breeder Test Reactor at Kalpakkam, there was a leak, primary sodium leak in the purification circuit cabin. We have a sodium ionization detector. Somehow at that time this leak was there that sodium ionization detector didn't function properly, and the operator, by the time he could realize, about 75 Kg of sodium had leaked out, and when we investigated, we found that a valve, which was in the purification circuit, at the top, the thickness was less than what should have been. So there -- there was a manufacturing fault. We looked at the other valves. Their thicknesses were good enough. So we didn't take any replacement, but this showed us that here is again need to see that all the valves manufacturing is done perfectly.

I was mentioning to you sometime back about the tsunami in Japan. We had our tsunami in 2004. Of course, there was a lot of damage and people dying in the Southeast Asia. Indonesia was affected. Sri Lanka was affected and I was at Kalpakkam there at that time when the tsunami happened. It was all over in 30 seconds.

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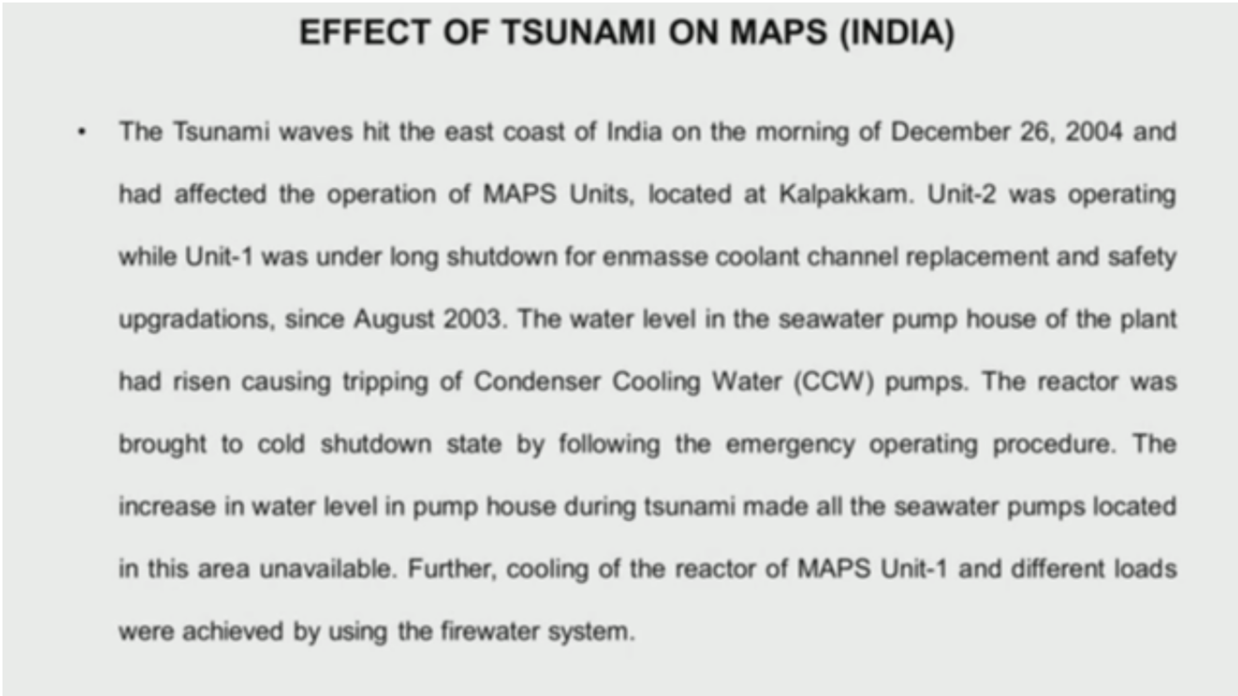

Let us look at the plant which is at Kalpakkam. We have the two heavy water reactor plants which are operating and the prototype fast breeder reactor was under construction. Digging was going on. The foundation was being laid. So because of the tsunami, the cooling water pumping station which is -- which pumps seawater for condenser cooling that was fully submerged in the seawater. So as a safety precaution, the Condenser Cooling Water pumps trip automatically. Once the condenser cooling water pump trips, no cooling for the condenser, so the condenser pressure will rise. The reactor also trips. Then everything became normal after about half an hour. Nothing happened. Everything system was okay. Then the sea water pumps which are located over sea, they were inspected to see whether they can be restarted and then they were restarted.

So here, basically, what has happened? In all our assessments of the flood level, design basis flood level, we need to give good margins in the design such that we take care that under no condition the whole plant gets submerged, but we were -- nothing happened. We could have come back to the thing immediately.

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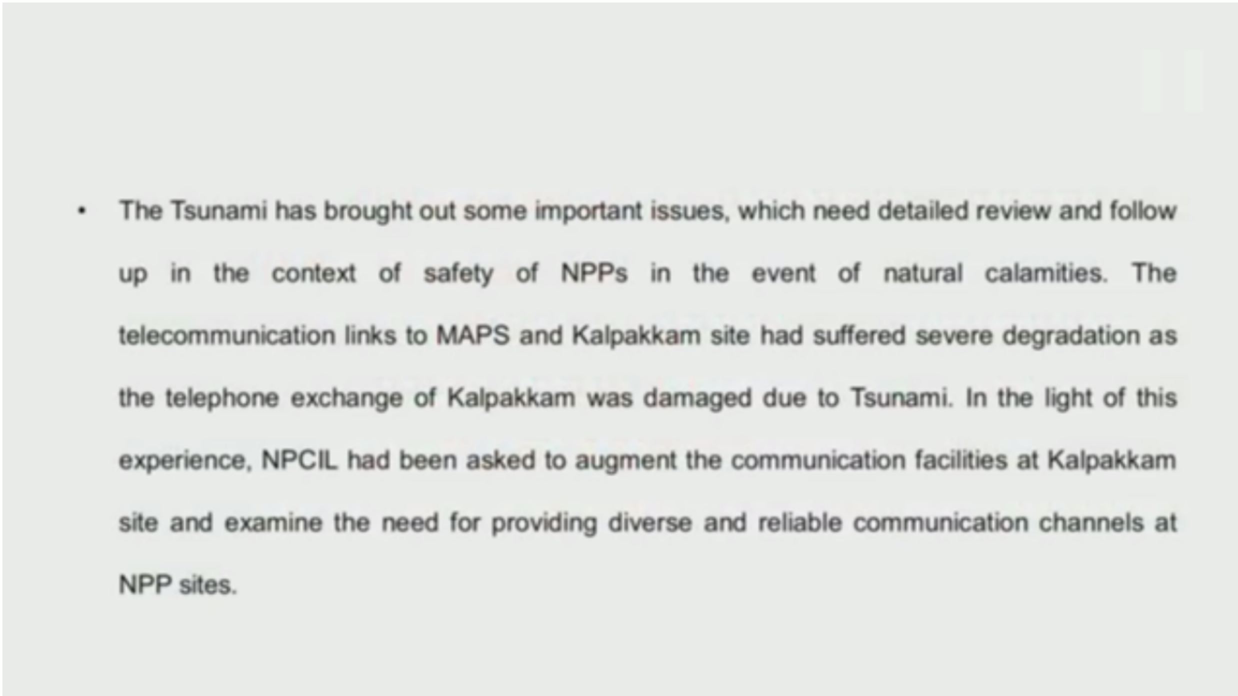

But one thing we learnt. During this event because of the tsunami, a bridge had failed between the township and the plant, and all the communication cables were going through the bridge. So the communication got snapped. So what happened? The operators there have to continue one more shift. They were worried about their families in the township where tsunami had affected very badly. So it showed the need for giving a reliable communication, wireless communication things from the plant, between the different plants, and all this all already exists between the different plants, but at the plant site the need for such things was realized.

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GLOBAL MAN MADE OCCUPATIONAL EXPOSURES (UNSCEAR:2010)

ACTIVITY	1975-79	1980-84	1985-89	1990-94	1995-99	2000-2002
Nuclear fuel Processing	560	800	880	800	670	680
Military Applications	310	350	400	420	378	331
Industrial Applications	530	690	560	700	790	869
Medical Applications	1280	1890	2220	2320	7440	7440
total	2680	3730	4040	4240	9278	9320

Now all of first might be thinking that okay, so many nuclear power plant incidents have happened. Of course, I gave you a history of only such events because the whole topic of our this course is on awareness on nuclear reactor and safety, but remember I mentioned to you in my first two lectures that radiation is used in lot of applications, industrial applications, for example, radiography of welds. It is used immensely in medicine, medical applications. You know the x-ray. You have the PET scan. You have the CT scan. Then you have cancer treatment, tumor treatment and whatnot and remember I mentioned to you at that time it is a 900 billion dollar business in USA. So you can see how much.

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GLOBAL MAN MADE OCCUPATIONAL EXPOSURES (UNSCEAR:2010)

ACTIVITY	1975-79	1980-84	1985-89	1990-94	1995-99	2000-2002
Nuclear fuel Processing	560	800	880	800	670	680
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So here I will give you a data of the exposures, occupational exposures means beyond where in such exposures have happened in different years and this is taken from the UN report UNSCEAR:2010, and you see what I have marked by red, so the maximum number of exposures happening is from the medical applications followed by your industrial applications and least by the nuclear fuel processing, nuclear power plant operation. Of course, military applications, again, is a one time or affair.

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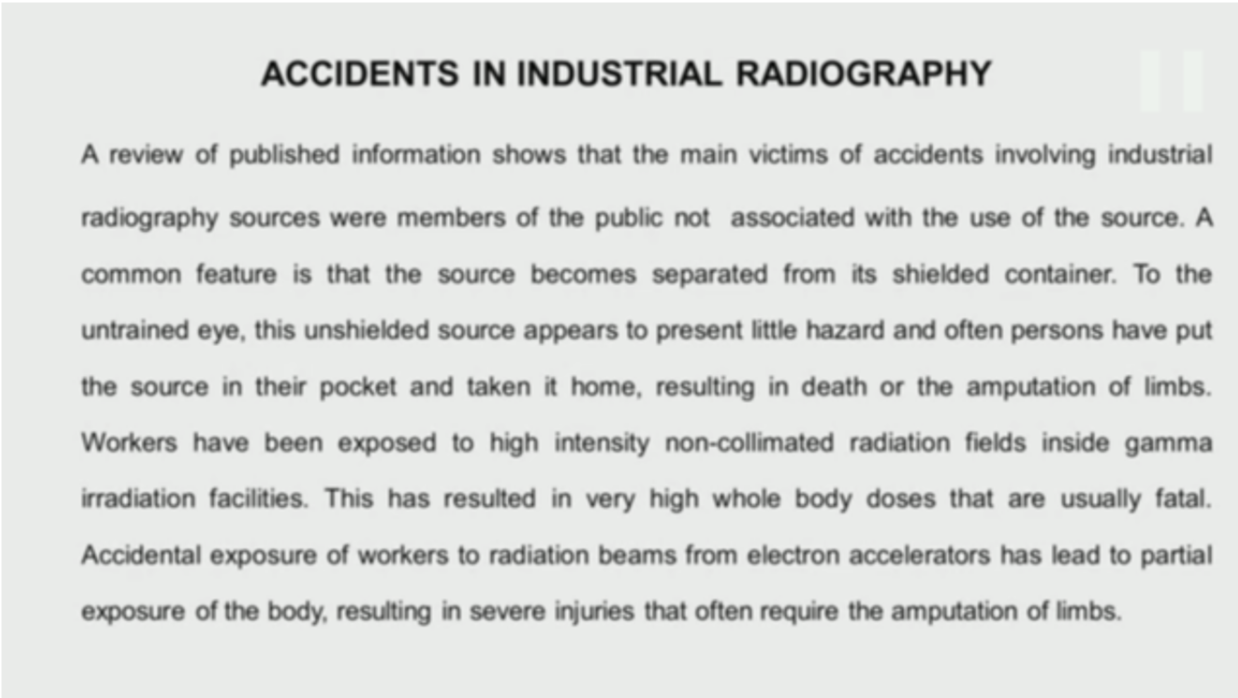

So here what sort of things are causing such exposures? Here this is all related to the radioactive source that you are using. The handling of the source is very important. It should always be put in a shielded container and then transported. During transportation, it is very important that very strict administrative control is kept and every person who handles needs to be, you know, taken for counting and see whether he has got any contamination. Every step, as we do in a nuclear power plant, this need to be done.

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ACCIDENTS IN INDUSTRIAL RADIOGRAPHY

A review of published information shows that the main victims of accidents involving industrial radiography sources were members of the public not associated with the use of the source. A common feature is that the source becomes separated from its shielded container. To the untrained eye, this unshielded source appears to present little hazard and often persons have put the source in their pocket and taken it home, resulting in death or the amputation of limbs. Workers have been exposed to high intensity non-collimated radiation fields inside gamma irradiation facilities. This has resulted in very high whole body doses that are usually fatal. Accidental exposure of workers to radiation beams from electron accelerators has lead to partial exposure of the body, resulting in severe injuries that often require the amputation of limbs.

So in many cases what has happened? The source has got out of the container and when the source is down, it just looks like a very shining metal piece. Some people may think that okay, it's a noble metal and put it into the pocket and that area near the pocket, your body, it gives you the radiation. You will have radiation burns. In fact, many -- some of the radiation facilities where gamma facilities for irradiation of, you know, foodstuffs, irradiation of, you know, grains take place, there also you have a beam of gamma rays. There they have people have had accidental exposures because they have not followed the procedures properly, and in many cases, they had to have amputation of the limbs also.

You must have heard one event in India that in Delhi a person who was admitted to the hospital with radiation burns, he was a scrap-metal dealer. Apparently, he has some scrap has been sold to him from the University of Delhi and when it was investigated, that scrap contained some radioactive source, which was bought about more than 30 years back. There was no record. So this only shows that there is need to follow the steps of written procedures, proper training.

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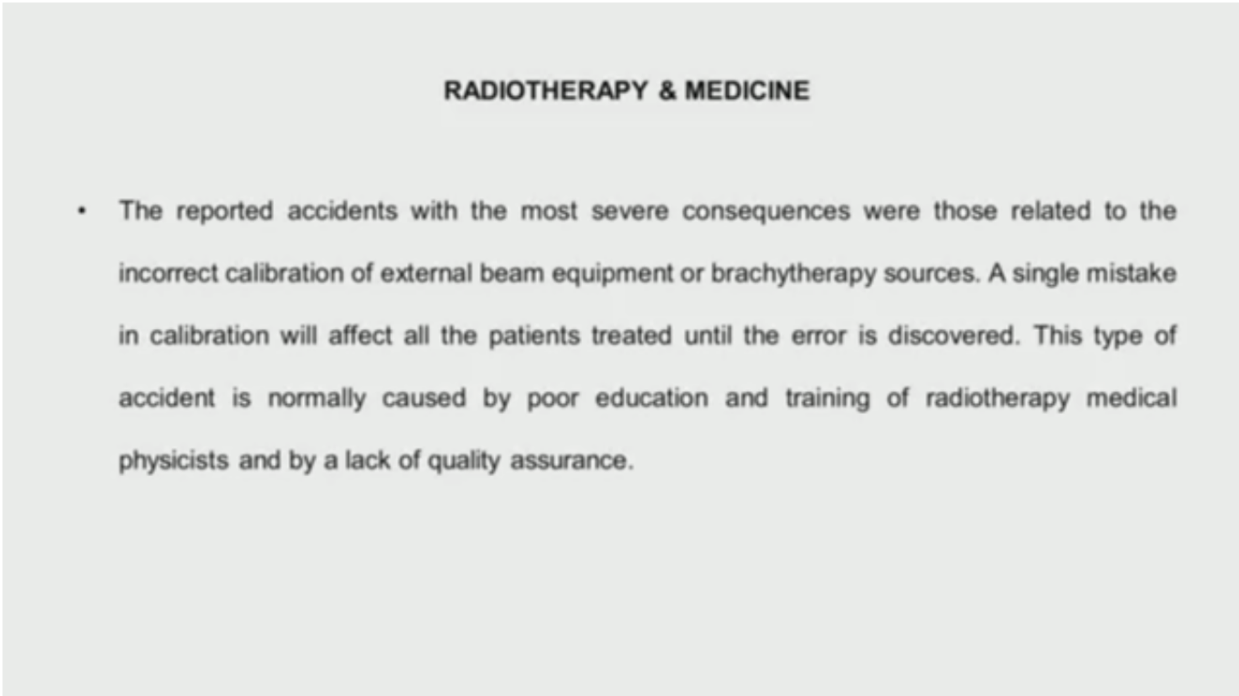

For example, I can tell you x-ray has been used by people much before the advent of our nuclear power reactors. In India, we have a lot of x-ray units, but the regulatory authority, which is the Atomic Regulatory Board, wants to do this. Every x-ray establishment should be licensed, but there are so many things which have come up like anything in the different states. So there is need for the different state governments and the central governments to get together and see that not only the x-rays are done in a proper manner, the person who takes the x-ray should also not be affected. So there are lot of things in the medicine.

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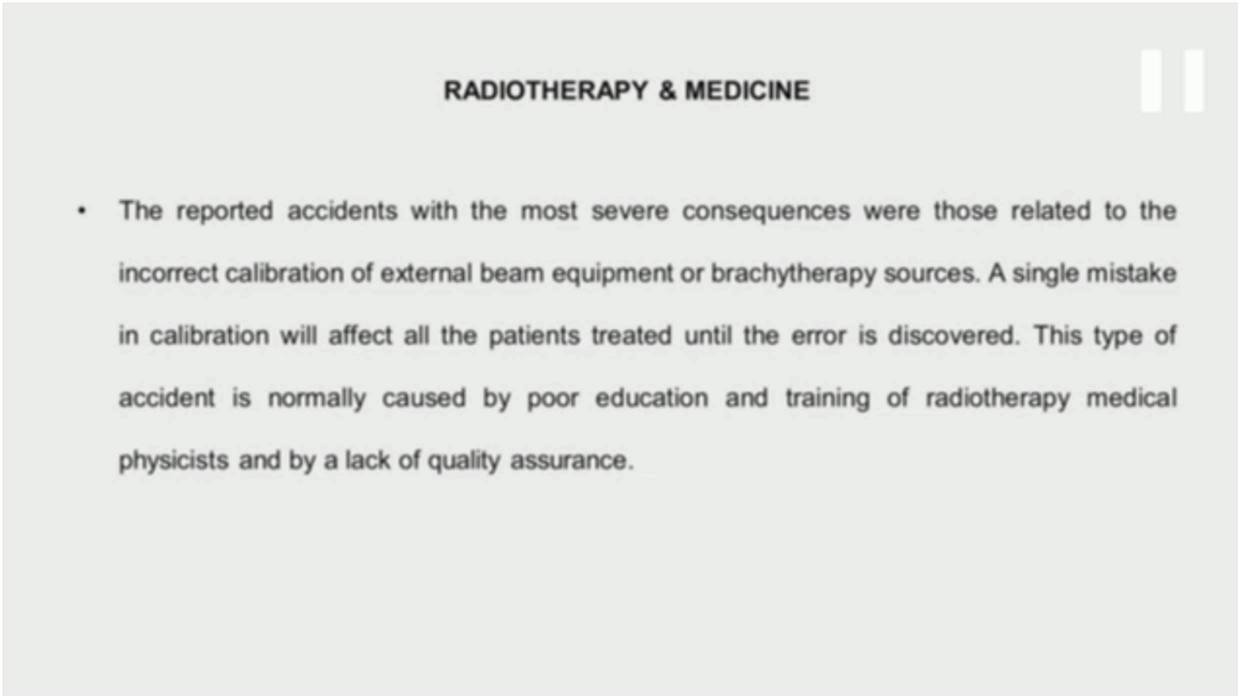

And one more thing which happens. These sources are calibrated. Then only you know their strengths. Sometimes if the calibration is not done and blindly a source is taken, this has happened in some of the radiotherapies wherein the activity was higher than what it was thought. So there is a large amount of scope to educate the people in the medical field in proper handling of this radiation and radiation devices.

So, in fact, you might see there are courses in medical physics in the different universities. In India, we need to increase the number of medical physicists who are aware of the use of all such devices which are used in the medical field and they are all licensed. All hospitals wherein they do this angiogram for the heart, they are all licensed by the reactor -- Atomic Energy Regulatory Board. Without that they should not operate. However, this needs awareness that not only the person who is x-rayed, even the person who is giving the x-ray can get, so all precautions must be taken in total.

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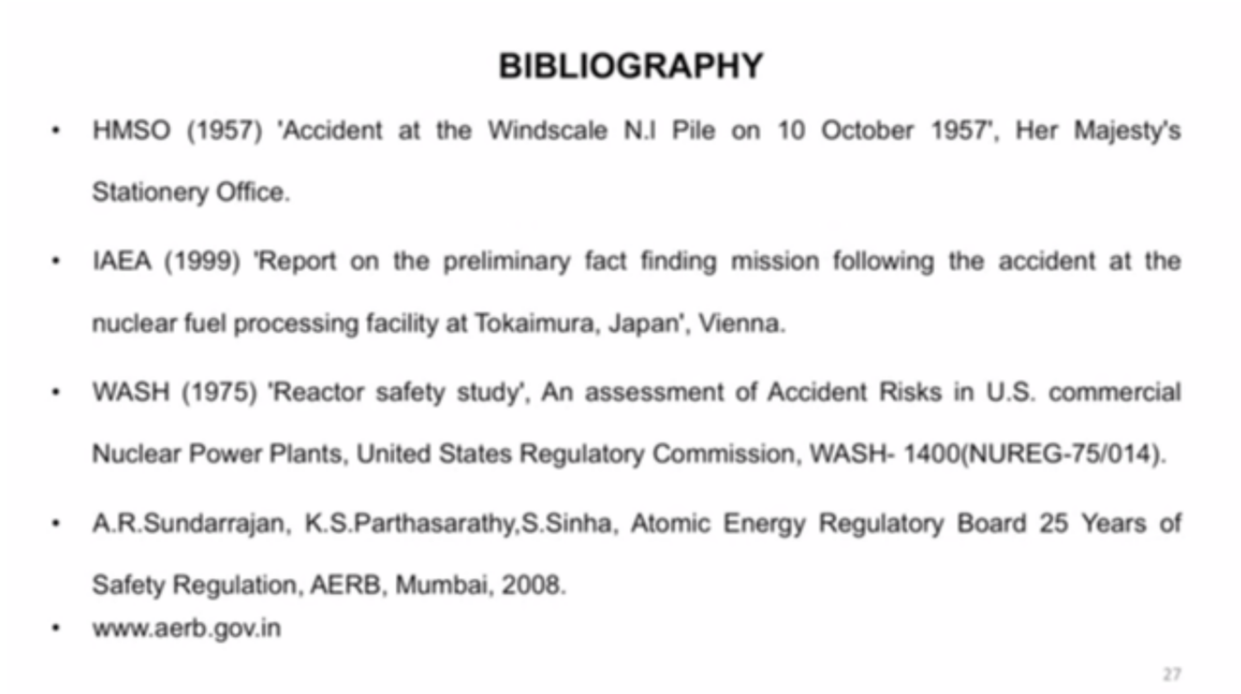

Now whatever material I have presented to you is based on the different data banks of IAEA, large number of reports. Nevertheless, some of the reports, which I have highlighted, out of this, the WASH 1975 report or it is called the Rasmussen study, this was one of the first ones to really list out all events. It's called as WASH-1400 and any nuclear engineer or nuclear scientist cannot say -- say that he doesn't know WASH-1400. This tells all the -- it -- it made a deterministic steady, a probabilistic steady and all.

This last report or it is actually a book which is available in this website of AERB which was published in 2008, most of the incidents which have happened in the Indian nuclear power plants, I have taken out of this publication, and when you go through this publication, you really realize that the Atomic Energy Regulatory Board in India is really doing a commendable job. It is really putting its foot down not allowing things to go further without compliance. Without understanding and without compliance, they don't allow any establishments to work, and this is really very clear in this publication, and you can see it.

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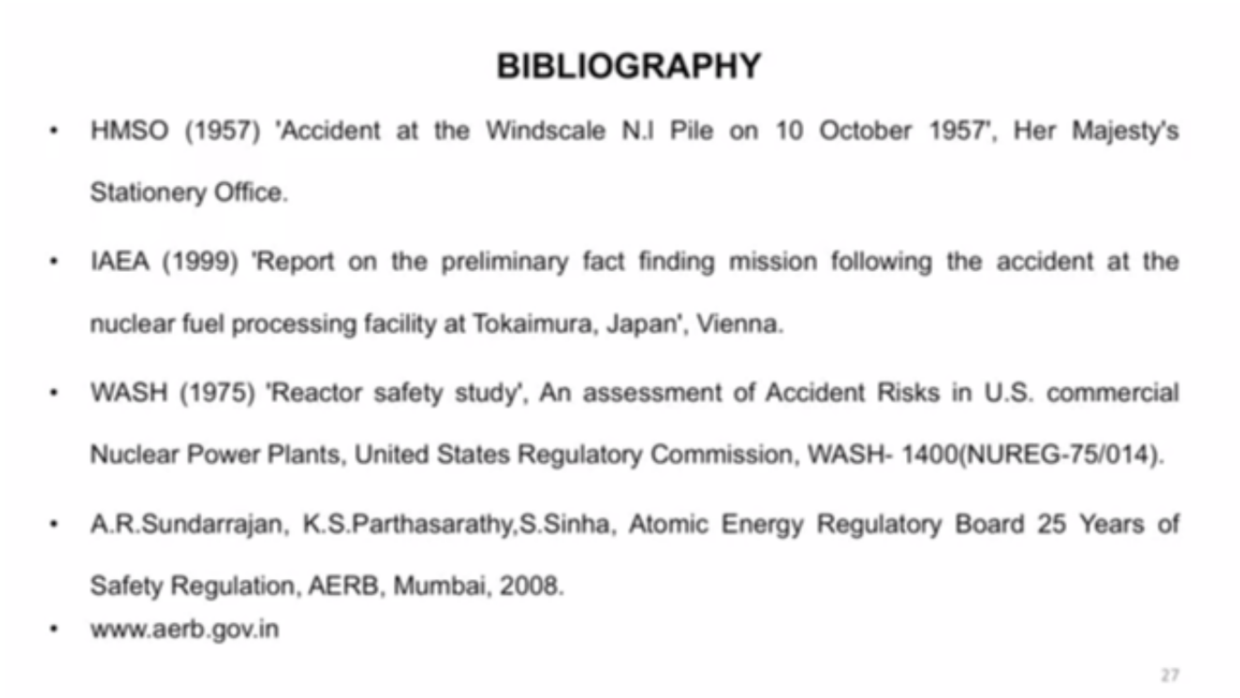

You can, in fact, download it from this website under www.aerb.gov.in under Publications, you will see the Silver Jubilee Book. That is what it is. Of course, I had the fortune of translating it to Hindi also. It is yet to be put in the website, and why I am telling you all this? Many people were agitated that there is a delay in the commissioning of the Kudankulam nuclear power plant. It was undergoing lot of tests, and in every tests, even a minor deviation, which was seen, the Regulatory Board has to go through it and satisfy itself that it was a minor deviation, it was not a design fault. Everything it has to get clear and that takes time. So we cannot just like that raise the power. We are -- our first and foremost responsibility is safety to ourselves and the safety to the public. That is our motto.

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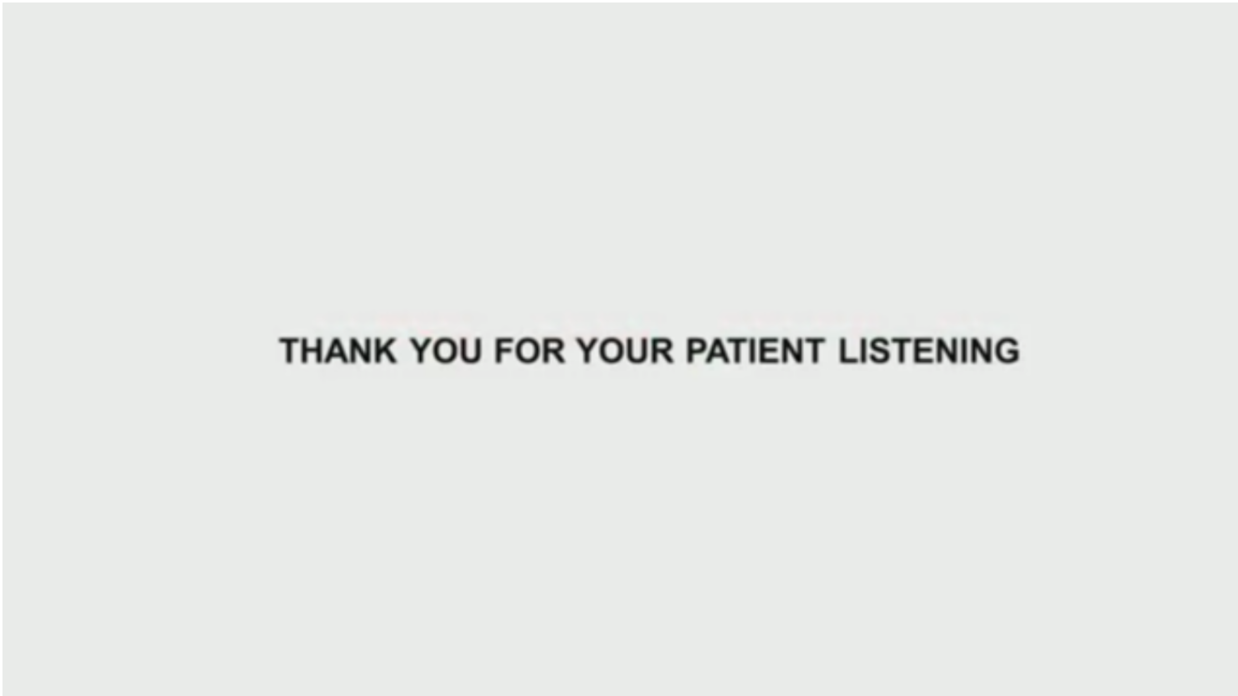

Thank you for this patient listening. I hope you have had a good overview of different types of incidents. We've also seen that the medical field needs a lot of upgradation in the procedures, training, and so that your health is assured and also the health of the workers in the medicine field is also assured. Thank you.

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