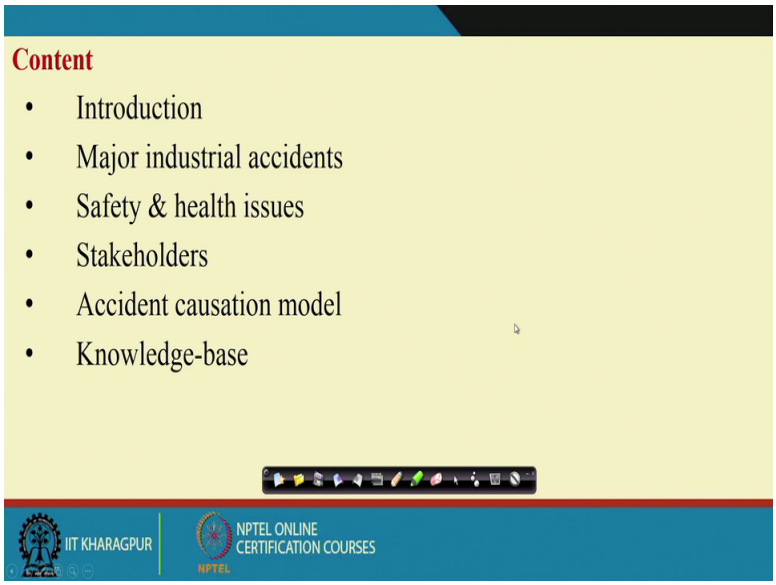
Industrial Safety Engineering
Prof. Jhareswar Maiti
Department of Industrial and Systems Engineering
Indian Institute of Technology, Kharagpur

Lecture – 01
Introduction to Industrial Safety Engineering

Hello, welcome to the first lecture of Industrial Safety Engineering. In today's 35 to 40 minutes of lecture, I will introduce this subject Industrial Safety Engineering.

(Refer Slide Time: 00:31)

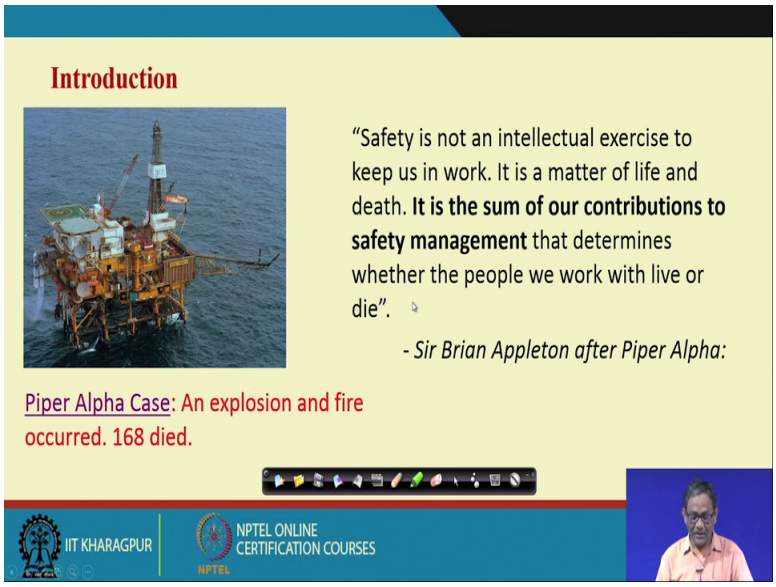


So, the content is we will see some of the major industrial accidents, what has already happened? Then safety and health issues, stakeholders, accident causation model and knowledge base, most of the information related to the figure to the past accidents to the models are taken from publically available internet sources and some taken from standard literature.

So, in the first lecture I want to give you what is this subject? Why this is important? And, what is the relevance of the subject to industry to the academy? And finally, what will be the basic requirements to know for the to go about or to learn the subjects, the subject as well as finally, some sketchy blue print that what is in total safety engineering? And in subsequent lectures, we will see that that more focused concepts and their elaboration will be made. And, then we will go to different techniques tools and so far so forth.

So, the syllabus is with you. So, you please go through the syllabus, as well as follow all the lectures whatever we will we will should give you. As well as the, I can say the assignments and also use the discussion forum platform. And I hope that you will enjoy this industrial safety engineering subject to the level expected. And definitely your knowledge on industrial safety engineering in particular and in general in safety engineering will be enriched with this with this hope I am starting this lecture.

(Refer Slide Time: 03:16)



(Refer Slide Time: 03:48)

First, I will I want to show you a case, which is piper alphas case that that we have taken a video and which is available. So, the video you first see.

(Refer Slide Time: 04:02)

So, you see that what is the disaster situation in piper alpha case? A mistake small mistakes may be initiated somewhere. And finally, it lead to such an catastrophic accident and a huge explosion and then fire. And finally, 168 people died. So, this is a break through incident I can say, because of this incident lot of further development has taken place. And I request all of you just to go through the piper alpha case and the reports available and then understand why this accident has taken place? And, whether safety engineering as such was applied in totally or not so, I am keeping it opened to all of you.

So, after the that incident happened and the enquiry everything has taken place, then you know that the sir Brian Appleton. What he has commented on this? Safety is not an intellectual exercise to keep us in work; it is a matter of life and death please keep in mind matter of life and death. So, if in your lifetime or if in our lifetime, we can say one life this is this is enormous. So; that means, everybody of us should be triggered to do something so, that the life of the people at work in particular or life of the people in general society can be shaped.

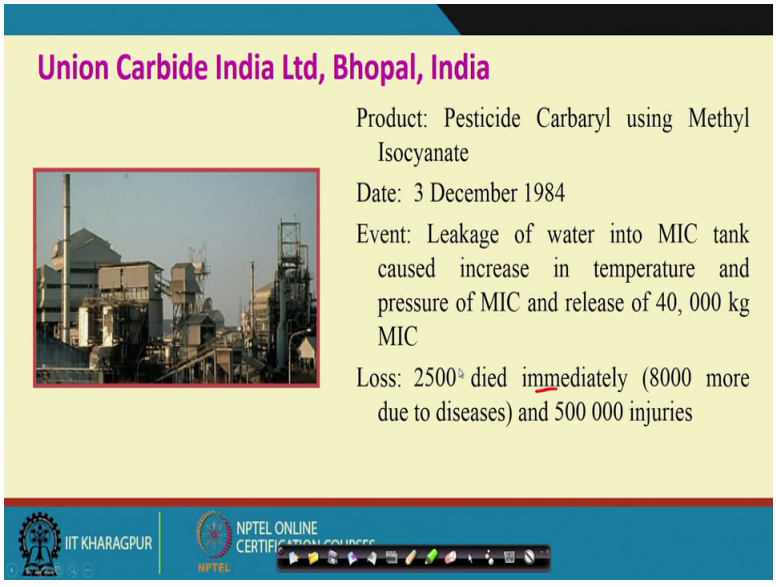
So, it is not an easy task as sir Brian Appleton says. It is a sum of our contributions sum of our contribution to safety management that determines whether the people we work

with live or die. So, we want to seek the answer to this question that whether, the people we work with live or die. What system you are giving them to work? Or what sys under what system we are exposed to work? So, that is whether this is designed in following the safety engineering principle or not. So, that is, what is the totality of this subject?.

By saying this I am not saying that we will be dissecting the piper alpha case and we will be showing you that what are the different failures? And what way that safety engineering principles are not applied in detail, but definitely we will not only this some other previous accidents we will also try to discuss, but this piper alpha case which open to all of you it is your work you can consider that is the prerequisite.

That you de you get the report it is available read it and with the mindset that that ok. How safety engineering? Whatever you knowledge you will gain in this particular subject can be used or where the gaps were there ok. It is not the, that piper alpha is the only case. So, you will find out there are many such accidents that has happened.

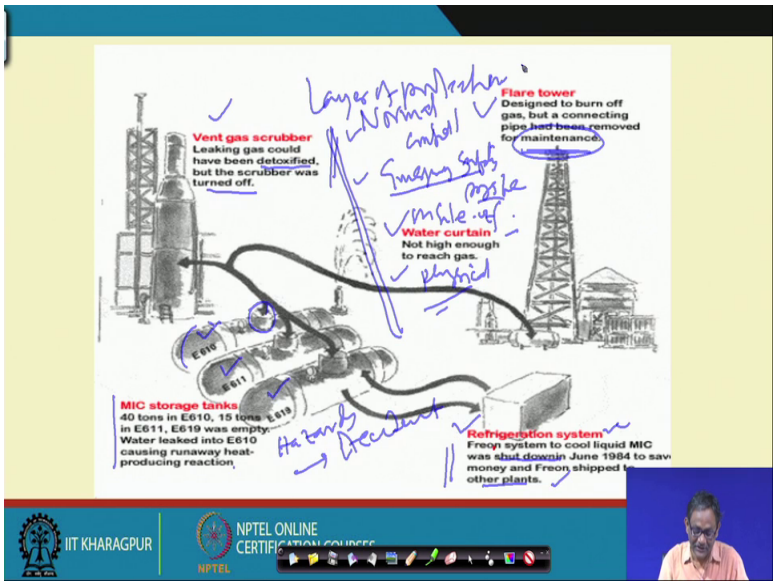
(Refer Slide Time: 08:48)



You all know that union carbide India limited Bhopal the case of 3rd December 1984 3rd December 1984, what happened, what was the event? Event was leakage of water into MIC tank caused increase in temperature and pressure of MIC and release of 40,000 kg of MIC. And, what is the loss immediate loss is 2500 people died immediately 8000 more due to diseases and pep 500 000 injuries and in fact, even today the effect is there.

So, can safety engineering help you to understand why such accident has taken place? And when you design the, or design a new system of similar nature. So, what are the things you have to do ok? So, if we go further you see that, what actually happened in union carbide case?

(Refer Slide Time: 10:12)



Here you see that this is MIC storage tank Methyl isocyanate 40 tons in E 6 1 0, then 15 tons in E 6 1 9 and 6 1 11 this 1 11 this 1 9 E 6 1 9 was empty 40 tons 15 tons in here 40 tons here and this one empty, water let into this what let into this and causing runway heat heating heat producing reaction. Then, you see that there are so, many protection measures refrigeration system. Fuel system to cool liquid MIC was shut down.

The design was that that a this it may happen under such situation that Freon system that will that will be used and to cool liquid MIC was shut down. In June 1984 to save money and Freon shipped to other plants. Another one you see water curtain not high enough to reach the gas, flare tower designed to burn off gas, but a connecting pipe had been removed for maintenance. So, few think maintenance. Here it is basically mar that is of cost or the benefits with business of a things. Here what happen the there is a water cut in which basically use, but what happened it was not that high the design problem.

Then, when vent gas scrubber leaking gas could have been detoxified by the scrubber was turned off this is a show people problem. So; that means, when we talk about such accident and it a these are these are high risk plans. And in all high risk plans, what

happen? The design will be such that there will be different layer of protection. So, layer of protection like this and this.

So, as a safety engineering, if you if you look into this then you will find out that there will be there will be normal control system normal control, which require for the day to day operation, then there will be emergency safety system, emergency safety system that if something gone wrong then how the system will behave. So, that that things can be system can be restrict to the normal.

Then, there will be one side upside counter measures even after that also the when accident has taken place then the consequence to be reduced. And there will be a physical contentment for hazard and basically that separating the hazard from the people of the target ok. Here, it was there, but having those things does not mean that it is a full safety engineering. It is the design point of view those things must be there. What else require? Well seek like the emergency control system counter measures all those things are basically, if I say that under high risk operation these all risk control measures, that risk control measures must be operational also.

They must work. Now, if I see here re refrigerating system is working, but it is not it is dedicated for this, but it has been bypassed to some other plant. So, what happened? It is it is not the design problem it is the problem with the maintaining the system protection system given to you.

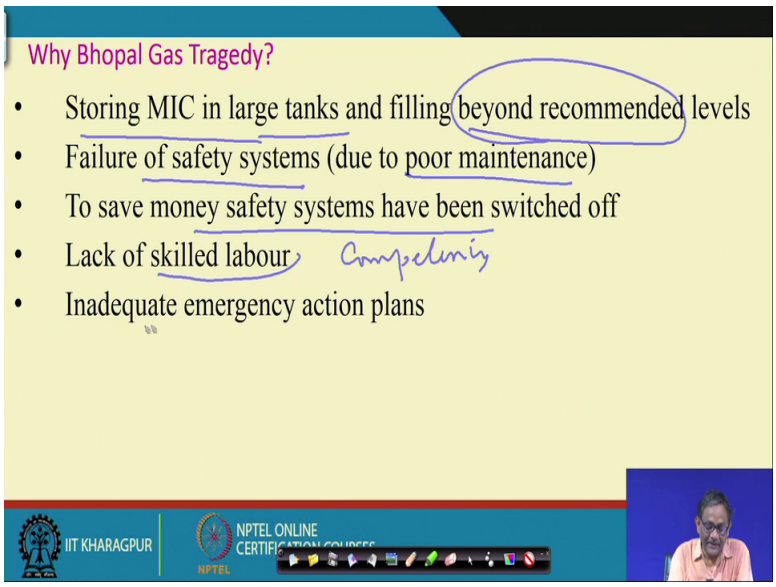
Similarly, here see flare tower this is also it was there the control system emergency control system was there, but what happened? Because of poor maintenance that connecting pipe that is that was not working. This was a design problem because the height that gas can reach that was not understood so; that means, the height is not sufficient enough.

And here you see vent gas scrubber that this is also another good ex so, that the gas whatever will come out that if can be de detoxified at the release point, what will happen it will not affect the environment as a whole and the people at society will not be affected. So, that not be affected that much will be affected, but it was it was basically turned off.

So, that means one thing is that you must have a proper design you understand that what are the hazards that can take place? And the hazards ultimately lead to accident. So, you have though identify the hazards and then hazard lead to accident hazard lead to accident and accordingly that there will be layer of protections layer of protections. So, all those things during design you have to understand and definitely these are there.

But, even under very good design system also this will happen if the maintenance, monitoring, control, all those things are not done properly. So, all those things will come together under safety engineering one is design, then you if you go by the system life cycle, when design, bill, operation maintenance, disposal all those things will be there at every time we will find out that there will be number of hazards. And, for every hazard there is protection measure and those protection systems must work and that is that is what also to be one is you design into the system you see that they are working. So, all those things are coming under safety engineering.

(Refer Slide Time: 16:37)



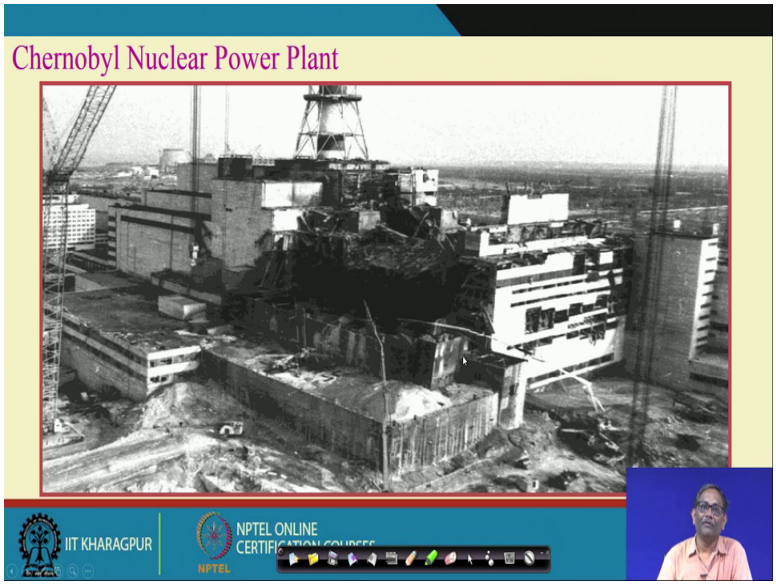
So, very quickly now we will see some of the other issues, but from the report there will like la reports available in it now a few of them just like I have written here, that storing MIC in large tanks and filling beyond recommended level beyond design level design recommendation you are filling up.

So, this is this is not permitted, but it is done. Failure of safety system as I told you that normal control then, emergency safety system onset offset counter measures like why

this detoxified that main scrubber was there. Because, if the gas is detoxified at the release point, then the a effect of con impact of gas will be reduced that is upside counter measures, but that was not working because of because these are all coming because of the maintenance control for all these things this is a poor maintenance.

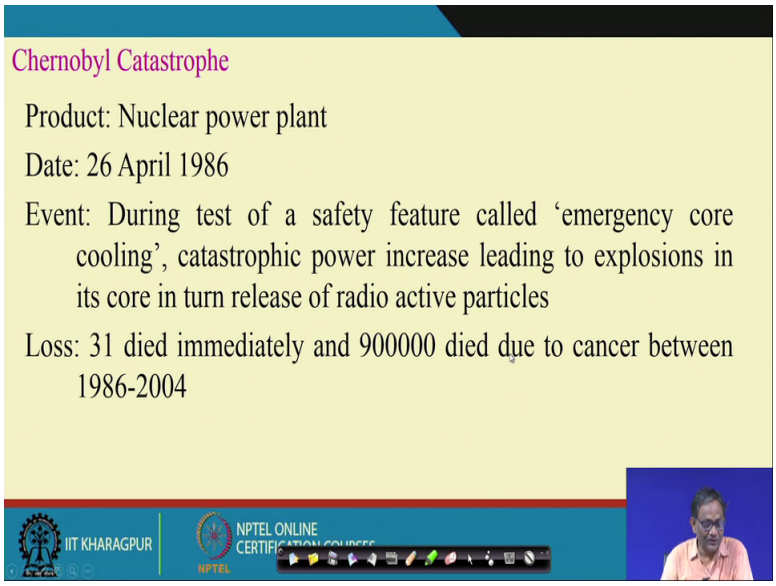
To save money safety system, have been switched off. I do not have any answer to this lack of skilled labor competency. And a inadequate emergency action plans. So, there are many more, but these are the few which are basically which are that should be talked about. So, that means one hand here what happened the design problem? One hand the on the other hand what happened the maintenance and operation problem? And all those things come um joining together ultimately leads to such disastrous accidents.

(Refer Slide Time: 18:30)



Another one Chernobyl nuclear power that you know I will very quickly I will see share.

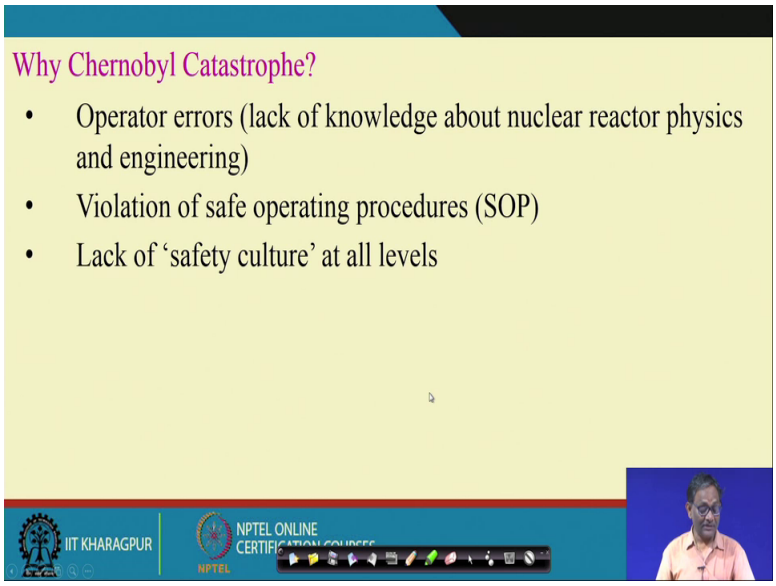
(Refer Slide Time: 18:35)



Actually, this is in 26th April 1986. During test of safety feature called emergency core cooling you require to have the domain knowledge to understand all those things. So, for ma to me basically this is what I am giving you the different example and with some information, but this is a nuclear power plant here. So, your knowledge about emergency core cooling and although how the nuclear power plant once that also require? But for here we are basically setting the tone that why this subject is so, much important?

So, emergency core cooling catastrophic power increase leading to explosions in it is in it is core in turn release radioactive particles and you know that 31 died immediately and this much died due to cancer between 1986 to this 4 2004.

(Refer Slide Time: 19:43)



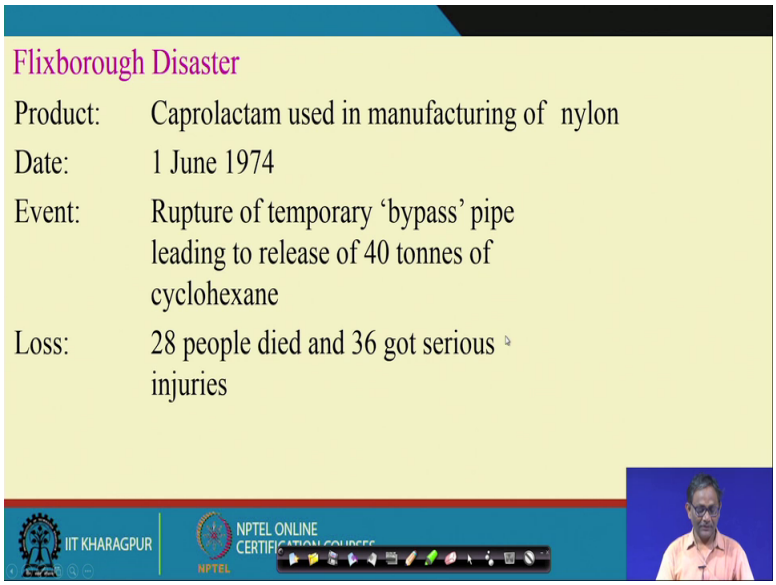
You see what is the what is the problem? Operators error lack of knowledge, I told you that la knowledge domain knowledge is very important lack of knowledge about nuclear reactor physics and engineering. This nuclear reactor physics and engineering it is part of that particular subject domain. It is not the part of a pa part of a everybody industrial safety engineering we will not be it is learning that what is nuclear reactor physics? Whether, what we will be learning here that, that how do you make it is your that the safety engineering is in proper place? So, someone wish a knowledgeable in nuclear reactor case he will be in the team so, that that the safety engineering is in proper prospective.

Violation of SOP lack of "safety culture" so, in previous example we have seen that there are design problem, there are maintenance problem, there are competency problem, here what we are finding out again we are finding out competency problem and SOP violation another one is a safety culture. It is a used thing, but we are now we will not be talking about safety culture in industrial safety engineering.

(Refer Slide Time: 21:00)

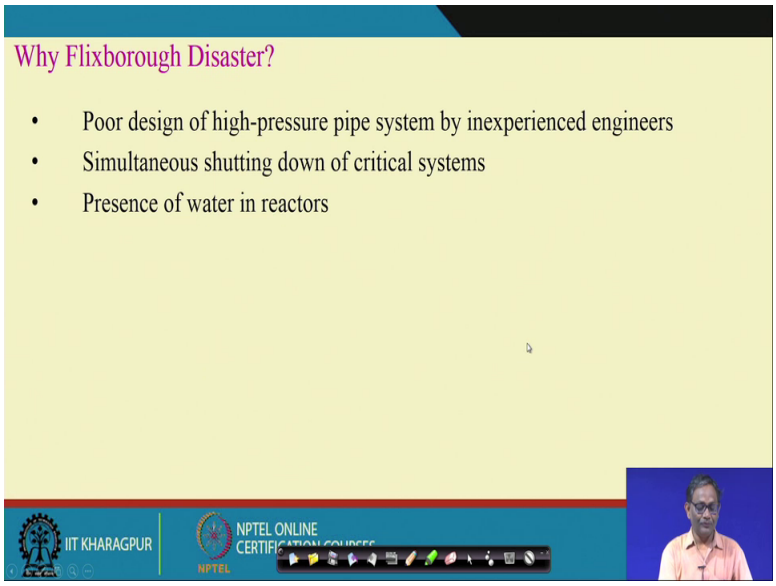
Here we gave a plant Flixborough, England.

(Refer Slide Time: 21:03)



In 1974 rupture of temporary bypass pile leading to release of 40 tonnes of cyclohexane 28 people died and 38 got serious injuries.

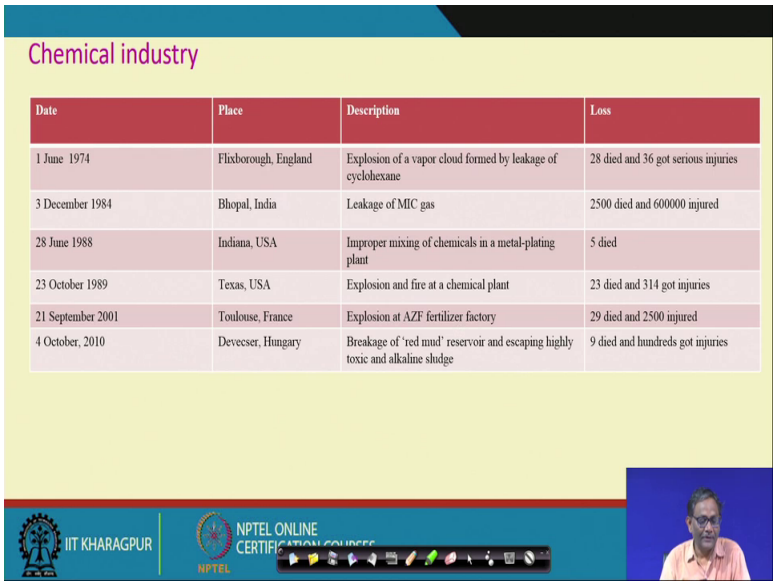
(Refer Slide Time: 21:15)



Poor design of high pressure pipe system by inexperienced engineering this cannot be tolerated. You when you are designing such high risk plant and you know that the people at work and the society has large may be exposed to such thing. So, you cannot design poorly. So, if you design poorly that you will carry for over the entire lifecycle of the system unless, otherwise it is rejected and relegent, but when you are designing such an high technology system. So, relegent you it is will not serve the purpose.

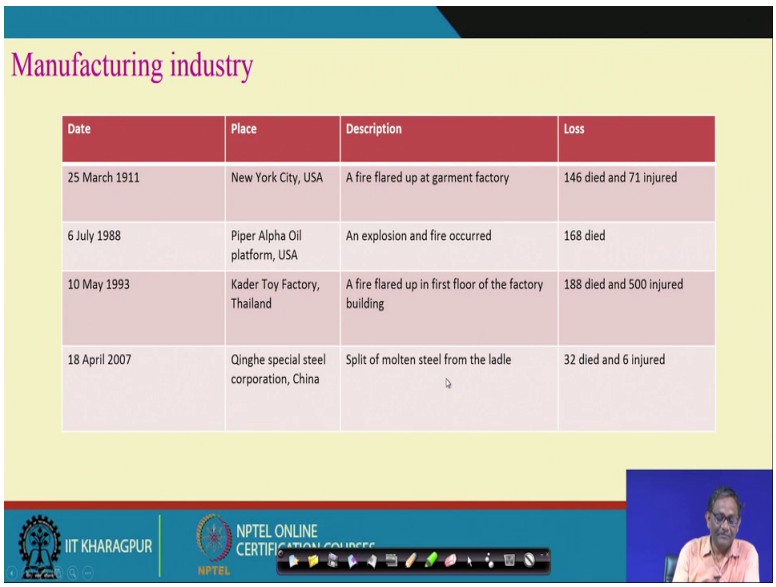
Simultaneous sati shutting down of critical systems, it is I can say this basically problem with the red operation shape operating procedure that what is should not be done we are dividing presence of water in reactors; So, more of your design and operation problem here.

(Refer Slide Time: 22:21)



So, the list is endless now you can see that I told here that Flixborough, England well Bhopal 1984 that la leakage of mi MIC gas, Indiana USA 1988 improper mixing of chemicals Texas 1989 explosion of fire. So, like this. So, there are many more in chemical industry.

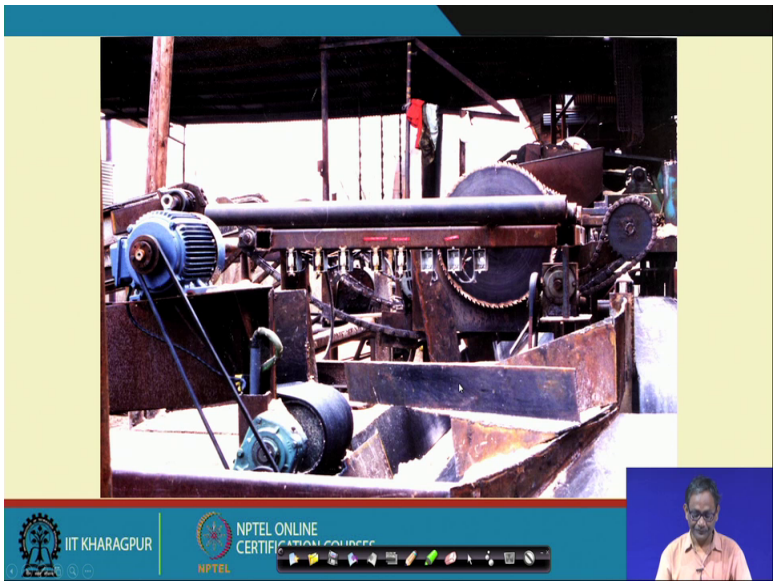
(Refer Slide Time: 22:49)



If you see manufacturing industry New York City, we say in 1901 a fire flared up at a garment factory 140 died and 41 injured in 1988 for piper alpha oil platform USA an explosion fire occurred, then 1993 Kader toy factory Thailand fire, 2007 that split of

molten metal steel from ladle. And you will see that um the fire industry in recent times also I think a in some hospital fire and in some building fire. So, many things are there, but this there are many more fire in accidents that have all, of the Deccan plane here under manufacturing industry we are listed some of them.

(Refer Slide Time: 23:43)



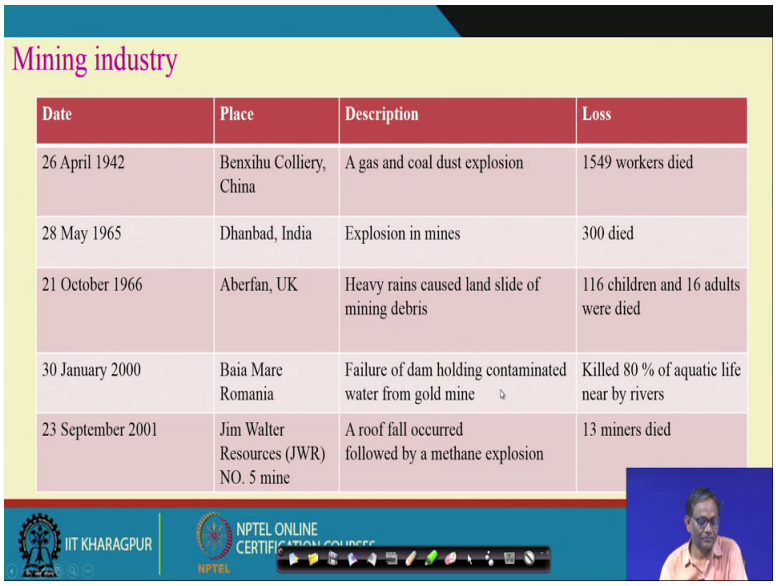
This is what typical picture I want to show you that how much unsafe it is there are moving parts, there are there are projected ends that. So, many link bar these are these are basically there open. So, and entirely the you see the machine is so, such a clumsy; there is no not proper housekeeping some brace here. So, see the this housekeeping is not proper the machinery not properly guarded. So, machine safety is also important.

(Refer Slide Time: 24:21)

This is a this is basically a working in a very hot and humid environment, you must see that there are there are there are places in a in industries, particularly large industry, particularly in high risk industry, you will find out such things for example, this you will get in steel plants.

So, when you design when you ma safety engineer must know that someone will be working here. So, what should be the protective measures? What should be the mitigating measures that should be there? So, he or she must know that or the team must know that what kind of hazards are available here already sourced, whether those hazards are sourced by design or by technology or it is, but basically unwanted coming from out of something else. Here more of health issues are also there.

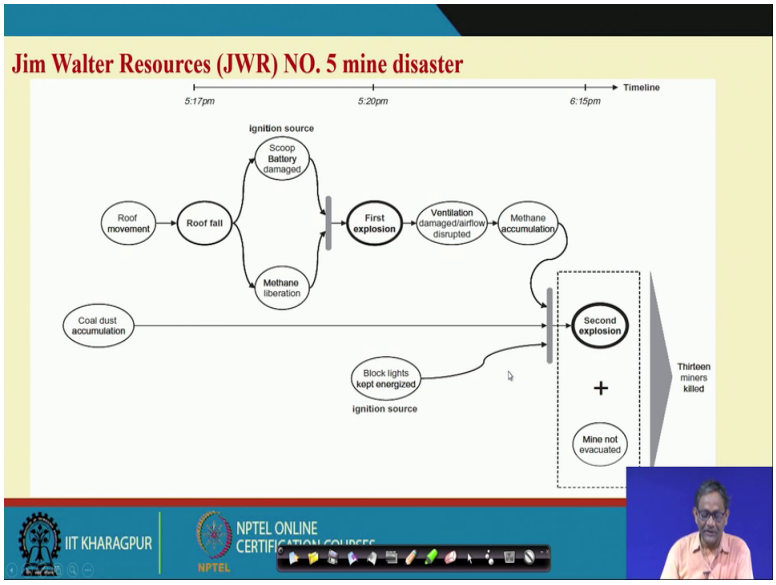
(Refer Slide Time: 25:21)



Then, mining industry; mining industry the number of that huge accident that catastrophic accidents are large also. Few of them you see that in China gas and coal dust explosion, how many people died 1549 workers left, but if you if it go down that even in 2001 23 September 23 September Jim Walter resources number 5 mine 13 miners died because of the roof fall accident and followed by methane explosion.

So, this the end is a the sorry the list is a end huge. So, if we go on listing down the mining accidents even in particularly India also that list is also very large.

(Refer Slide Time: 26:15)



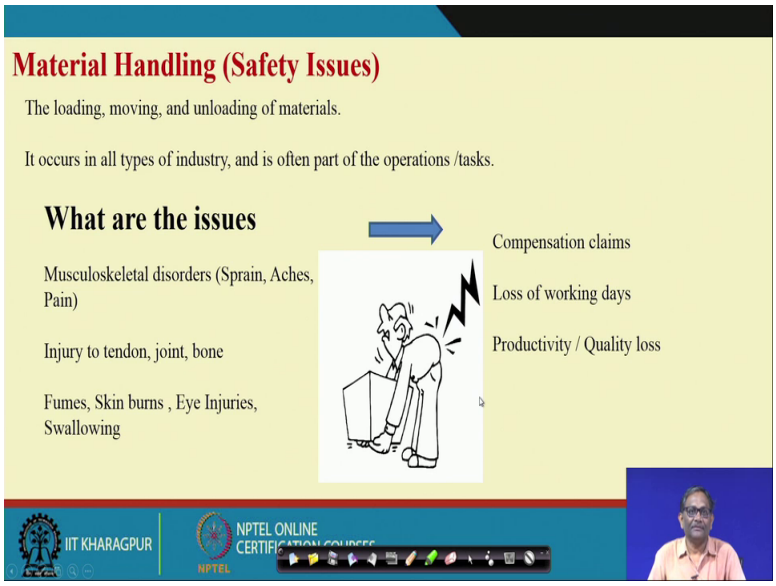
What happened to this mine disaster case? The because of may be poor support design or poor method of work roof movement beyond the design level, leads to roof fall at 5 and 517 pm. Then there are ignition sources scoop battery damage, then methane because of roof fall methane also exposed. Now methane is the source what I say the combustible material? And there is scoop batter damage from there the ignition source and you the ventilation is there. So, these 2 combine first explosion taken place.

Now, after first explosion what happened ventilation damaged and air flow disrupted. So, methane accumulated here. And in the meantime coal dust accumulated, then block lights kept energized ignition source remained there. So, cold dust methane and everything coming together with ignition source a huge explosion second explosion taken place. And, the mine could not be evacuated and as a result what happened 13 miners killed ok.

So, this is basically now is it not a safety engineering problem it is purely a safety engineering problem, roof movement roof starter movement should (Refer Time: 27:37) mechanic issues. So, design of that support system. Now, the scoop battery that will get damaged, but it should be fuel safe methane liberated explosion taken place ventilation system got damaged. So, if you can if you have eliminated this part nothing would have happened or eliminated this part this could might have not happened ok.

Or eliminated this part some control somewhere missing that is why the accident has taken place started from hazard to accident roof movement coal dust accumulation these are all hazards. So, ultimately because from hazard with influence of some other inter intermediate events finally, lead to accidents. Safety engineer must know that how from this hazard to accident that what is the path? Those things in the next few class; in the concepts I will be telling you what are those things?

(Refer Slide Time: 28:46)



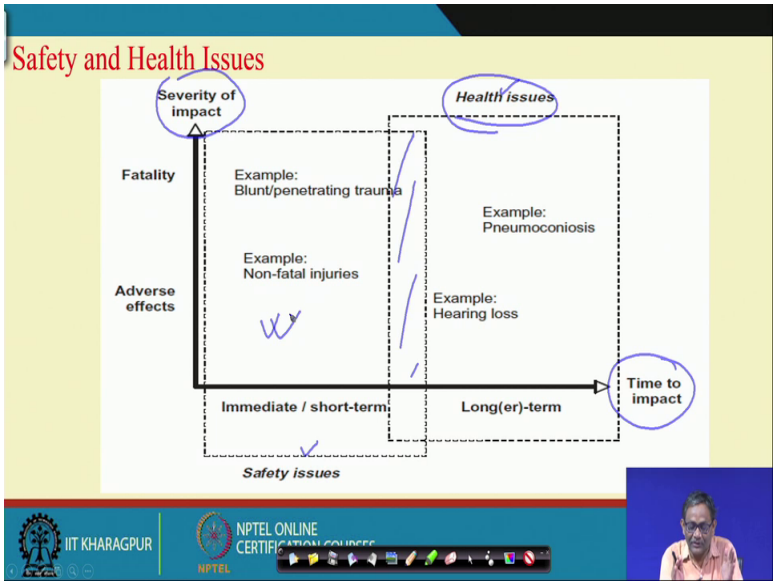
Now, big issue is material handling so, material handling more of health issues as well as that health issue also lead to safety issues. So, you cannot ignore material handling there are methodized materials handling that manual material handling ok, but whatever may be the case that safety issues are very very prevalent in material handling.

(Refer Slide Time: 29:13)

Construction working at height, you see the different heights people are working it is a huge of gravitational energy. So, it will may fall. So, what is how safety engineering will help you here? Is it possible that the safety engineering concept ultimately give you some

design solutions, some engineering solutions, I it is up to yes it is there. And, you have to find out how to apply it? This is possible if you know if you have hazard knowledge, if you have design knowledge, if you have previous experiences and if you have the total safety engineering concept the blueprint, you can apply step by step and finally, you will be able to avoid many accident not only in the construction in all industrial situations.

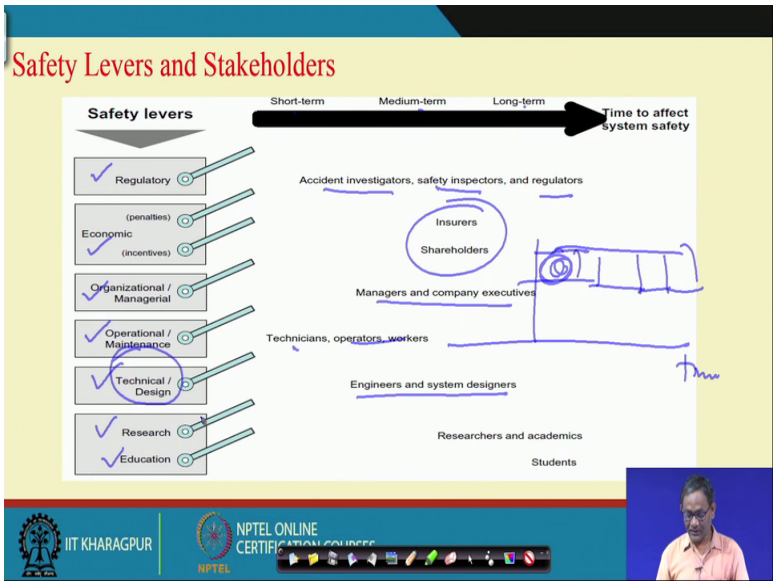
(Refer Slide Time: 30:08)



So, with those examples now I want to demark make the make it clear that what is the differences between health and safety issues. See, it is basically you have to think from the time of impact. And severity of impact is here. If the time of impact is long term it is health issues. If immediate a immediate or short term, it is usually safety issues there is overlap between health and safety ok. So, a worker exposed to may be a material handling job with which will prolong of what posture suffering from musculoskeletal disorder will come under health issues.

But, the same worker when working doing material handling heat by object or something fall on him that immediate this is safety issues; The safety and health issues may be one is may be caused to the other, but they basically be for people at work they belong side by side. So, there is also certain amount of overlap. So, we in the subjects what we are we will discussing it is on industrial safety engineering non not health, but many of the concepts can be applied in case of health also, but we will not dictate anything related to health may be some example comes somewhere, but primarily our work is safety issues.

(Refer Slide Time: 32:01)

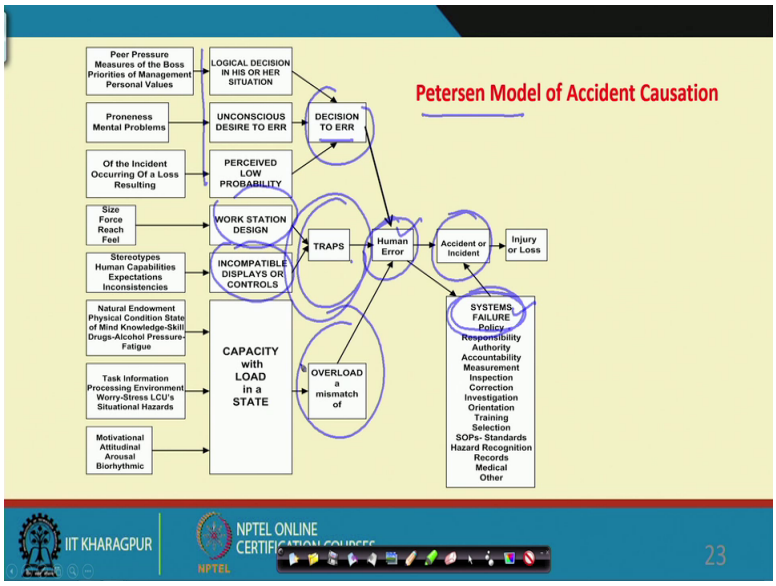


Who are the responsible? Who are responsible to time or affect short term, medium term, long term, who are the bodies or the ka stakeholders, regulatory, economy, organizational, operational, technical, research, education everybody. So, a design engineer who has designed the facility the product the machine the process is equally responsible for failure for safety problem. The operational maintenance people responsible, organizational management responsible there are different regulatory bodies they are also they are also responsible in the sense they also on should contribute, they are contributing in terms of accident investigation safety inspection and regulators.

Economic insure insurance, manager complex technician operators worker engineering system design, but from safety engineering point of view I can tell you that our measure consult is the design part. And, we believe that that if I start from these sides about this is my design, then you built then your operation, then maintenance, then this was already a life cycle life cycle. Here everything you must understand, that what are the different types of ha hazards that are exposed to by the by the exposed by the workers.

So, and education research I am I am not sure how much we are triggered to this because even today I B tech courses do not have this industrial engineering subject, for I such safety engineering subject except for a specific branches; like environment, like health, the safety is equally important and I think there should be and that should be basic course for all engineers as at least.

(Refer Slide Time: 34:20)



Now, I will take 5 minutes of time just to explain you that whatever I had told so, far the different accident has taken place and lot of examples we have seen, but there can be model which will which will help you in explaining what is happening? So, in the subsequent time you will also discussed in different ways may be some of the things what is here or another place, but grossly that there can the Petersen Model is a very good model. It talks about that accident is as per Petersen Model human error and system failure are responsible.

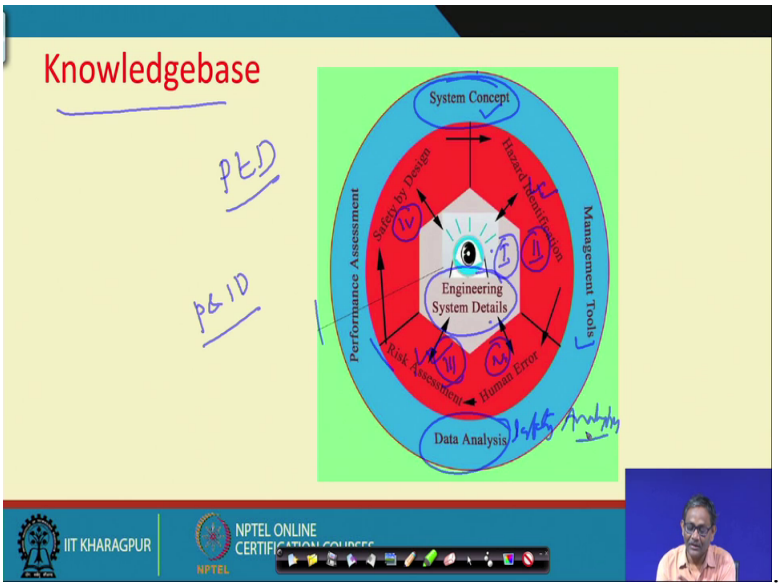
Now, when a you talk about system failure system failure is human, but human error is not human behavior that is what we are saying? Human error is a more technical than human behavior, which is more social or behavioral. So, now why human commit error there will be decision to error or may be trapped to commit that error or overload condition. And, then why decision error there are different regions, what do may trap work station design incompatible display of controls. So, it is basically system design point of duty for it.

Now, capacity with load in a state basically what now it is not the physical capacity it is the mental capacity, which is basically coming into consideration. This is one kind of model, but the safety engineers will be more of interested more interested for this, more interested for this also ok.

So, why system fails? What are the regions of that failure? What are the sys systems break down structure? What are the components of system all those things there inter plane between different components? Whatever the design problem? Whatever the upper maintenance problem? What where the problem lies? What will be the um be the safety engine engineering blueprint? How many hazards are there how these hazards will ultimately converted to accident? What are the paths from the hazard to accident? So, all those things ultimately you have to determine.

And that to be that you require to determinate the design stage, at the during design you must anticipate all those things and put prevention mitigation all those things in subsequent class, you will see that what I mean to say about the prevention mitigation hazards hazard accident part and all those things.

(Refer Slide Time: 37:28)



So, so, suppose you want to know um that, what will be the your knowledge base? How do I know that yes I know safety engineering? The knowledge base is very very systematic also. First one is system concept. The system you are designing here I am using the word system it may be product it may be process a combination of product process many things system concept.

So; that means, the knowledge about the system, what do you mean by knowledge about the system means the design knowledge. The system is designed to serve a pa particular par specific purpose, particular period of time may be. So, and for the entire life cycle of

the system the design knowledge you must have, you know that the how the different components function? What are the design intended function? And with the what are the different parameters? What are the different failure modes? So, many things all design knowledge design knowledge is very very important that is basically system.

A system concept you have to use to know that whether the system you are designing you have full understanding of this or not ok. And that system engineering details that is very very important. Engineering system details if it is a chemical reactor, you must know that what is P and ID for this piping and instrumentation diagram. Then through this diagram you will understand that each of the element component at this diagram, what it is this for engineering motive? It is the eye, if you do not have the system knowledge, the engineering details of the system you are not fit for safety engineering for that context ok.

So, this is the first thing. So, you must know how to represent a system and you must know what are the engineering details of the system and by engineering details system detail inverse in the that material design also we have to know not as such, but the required system engineering knowledge is important one. Then what happened the first step first step is hazard identification, that with multiple hazards. That once you identify hazard then ob e and then risk assessment. So, this is my priority one, then you must know this you must know this you must have concept of this, you must have the concept of human errors and ultimately what happened this hazard identification human error risk assessment safety by design, these will basically leading to prevent to design, PTD: prevention to design.

And what do you require your from knowledge point of point of view technical technique based are the system concept important, there are all different management tools that is required there are performance assessment this are require these all help you in actually doing in this safety engineering. And data analysis I will share now safety analytics, it is a data driven one also.

So, you must have the system knowledge engineering details, you must understand how to identify hazards? What are way human can compute create error, there will be another one that software error software, then all those things finally, lead to risk assessment, after risk assessment you will quantify a you will basically what happen you will identify

what are the areas where improvement is needed? Then you must know what is safety by design? And, then these management tools performance assessment tools data safety analytic tools all will be used in between to get the better result.

I hope that these make sense to you and ultimately this is not the entirety or of ma the knowledge based it is it is a multidimensional interdisciplinary case. So, many more things will be needed in between, but this is what is now the basic requirement for a for a safety engineer? Ok. I hope that subsequent lectures you will also enjoy equally thank you for joining this particular online course and hope for the best.

Thank you very much.