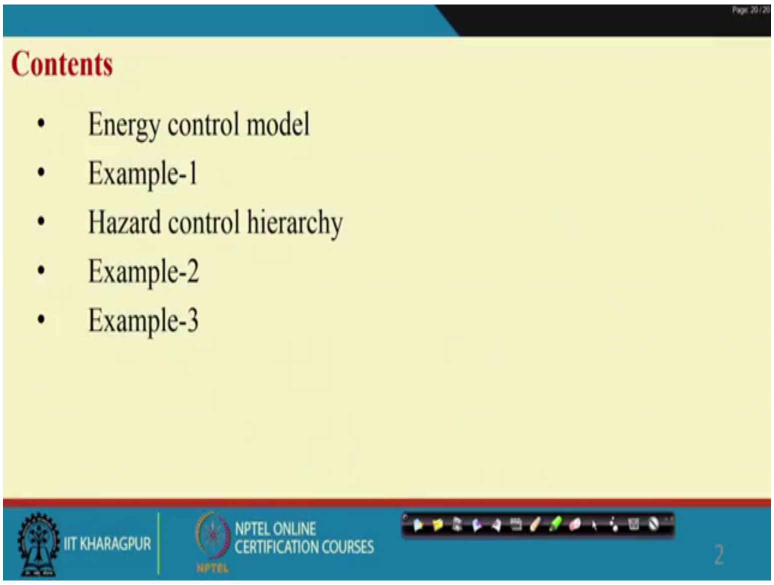
Industrial Safety Engineering
Prof. Jhareswar maiti
Department of Industrial and system engineering
Indian Institute of Technology, Kharagpur

Lecture –24
Energy Control Model and Hazard Control Hierarchy

Welcome to this lecture on Energy Control Model and Hazard Control Hierarchy; Energy Control Model and Hazard Control Hierarchy. So, hazard control hierarchy is known to you maybe because you might have heard of this. But energy control model I do not know that whether you know or do not know, but we will combine the two, and half an hour of time we will see that what is it and how it will help in our overall interest that is prevention through design. So, let us see the contents. So, we will discuss energy control model.

(Refer Slide Time: 00:59)

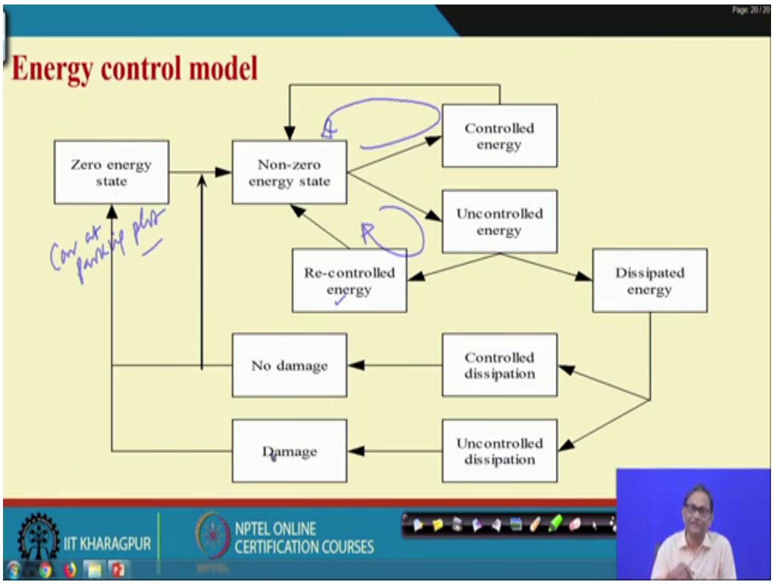


Then followed by an example, and then hazard control hierarchy followed by two different examples. So, let me tell you the background here. Actually what you want to do in safety engineering? In safety engineering you have seen that there is hazard. And hazard ultimately leads to accident. So, that is basically potential risk and realized risk. And as safety engineers I told repeatedly that your job is to understand this path. And finally, you put barriers either in terms of prevention or in terms of mitigation. So, that the path will be broken, if you put in terms of prevention that is always better, because it will not lead to the accident to happen. But there is the probabilistic view that everything is random. In some part will be random not the totality. So, there be accident, and accordingly prevent mitigation is also very, very important concepts and you have to give that mitigative measures what I where's mitigative measures must be there.

So now in this particular lecture, we will try to find out that how to come to those mitigative preventive measures. Particularly, or the and the mitigative measures prevention and or mitigation measures, that is what is our job today. It is not that we will see that exactly the context specific preventive measures or mitigitive measures. It is basically we are basically trying to give you some ideas or some principles so that once you know the total path from measured to the accident and also to the ultimate accident scenarios.

So, then what will happen you will be able to put the barriers in terms of the hazard control. And there is an hierarchy of control, hierarchy means something is better than the others. If you go through the hierarchy, you will find out that that may be the top one is the best, and bottom one the least effective in terms of prevention or mitigation as such hazard control. So, this is the background. Now let us see the hazard control energy control model.

(Refer Slide Time: 03:39)



So, let us take one example suppose a car. Now if we car at the parking, car at parking plot. So, it is not on nothing so, car at parking plot. So, it is 0 energy state; in the sense that there is no kinetic energy involved there. Only if you say potential energy with reference to mean c level that is a different part, but we are not going to that level of energy. So, here what we are saying that as it is not on, there is no engine running, and there is no movement involve this is our 0 energy state. Like machine is basically shutdown condition. But if it is a pressurize storage pressure like awards, what we have seen the pressure tank where the within the tank if it is it completely discharged then that is basically the 0 energy state. So, if you when you start that means, switch on and then ultimately you start the car. So, it basically start igniting fuel, and that mean non-zero energy state start it.

This non-zero energy state a can be under controlled; so, long you are a suppose you are the driver, you are able to maintain the energy in the since the speed of the car within your level of driving competency and; obviously, with reference to the road condition other traffics. So, that is basically controlled energy. So, that will happened in the industrial situation also and the given system. So, it will be under controlled state. Now, let us say that you have increase the speed in such a manner that ultimately and there is a traffic coming or maybe another car coming or another bicycle coming from other side, and the and when you saw this one and that the cycle coming at that time if you put the break.

Then there is a possibility that, that you will not hit the cycle or the other car coming towards you and you will control the; when you will be able to manage the safe distance then the re control, re controlled energy takes place. Means, breaking ultimately control your speed and nothing happened. So, you are safe that is the re control energy, but as the car is still moving and it is basically non-zero energy, going back to non-zero energy states. So, that means what happen even in the industry situation also; when plant under operation so that basically it will be under normal operating condition.

So, long it is under normal operating condition it is basically controlled energy. Now what is uncontrolled energy? Basically, the when you go beyond the some deviation takes place beyond that is normal these normal requirement. So, energy will be uncontrolled, and if by your and protection configuration, you are able to re control it, then ultimately what happened? It will be again under normal condition. So, that non-zero energy state, but under normal condition that is re controlled energy.

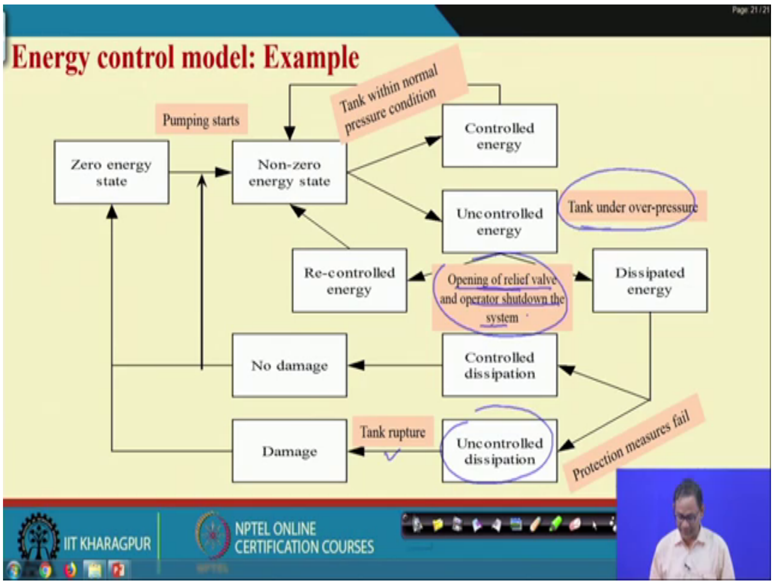
Now, what it may so, happen that so, while you are driving the car, you have seen the other part counterpart a maybe and much later state, in that case in order to safe that particular person or the property, what you will do? You may take a different route and in that case you what will happen, and then you may save this. But your intention was to go to a certain direction that does not happened, but what happened, but you going to a different dimension you lost your time. So, that mean you have loss some of the energy that is the distributed energy, but these dissipation is controlled dissipation, because no accident has taken place.

But the worst situation is that you have hit the cyclist. So, the cyclist will fall down and if it is so, worst condition that that person may die. So, in that case it is basically uncontrolled dissipation leading to damage. So, the dissipated energy can be controlled dissipation, can be uncontrolled dissipation. Under controlled dissipation there will be no damage, but ultimately depending on the situation that means the you may go to the non-zero energy state or the 0 energy state. But, when the uncontrolled dissipation are taken place so, ultimately damage has occurred and you will ultimately go back to the 0 energy state with lot of damage.

So, this is: what is the nutshell the energy control model. So, that mean you when you have your plant, you please control the energy, the way you design your system from the controlling the energy, point energy then you are you know that what is the inherent safety or safety of the system that you have designed. So, that means, there is normal intent normal conditions. So, your system should operate under this condition. Even though there will be abnormality or uncontrolled energy, your there must be a system must be configured in such a manner that, this uncontrolled energy can be re controlled and it will again operate under controlled energy state.

But they are even then there maybe situation when there will be some kind of dissipated energy; which we means the some kind of deviations that ultimately realized, and then some energy is lost. So, that dissipated energy may ultimately controlled in such a manner that no damage take place, except the energy lost or it will be completely uncontrolled and it will lead to a huge damage and which is totally undesirable, ok. So, this is basically energy control model. Now, with reference to these energy control model I want to show you one that pressure tank system what we have discussed.

(Refer Slide Time: 10:40)

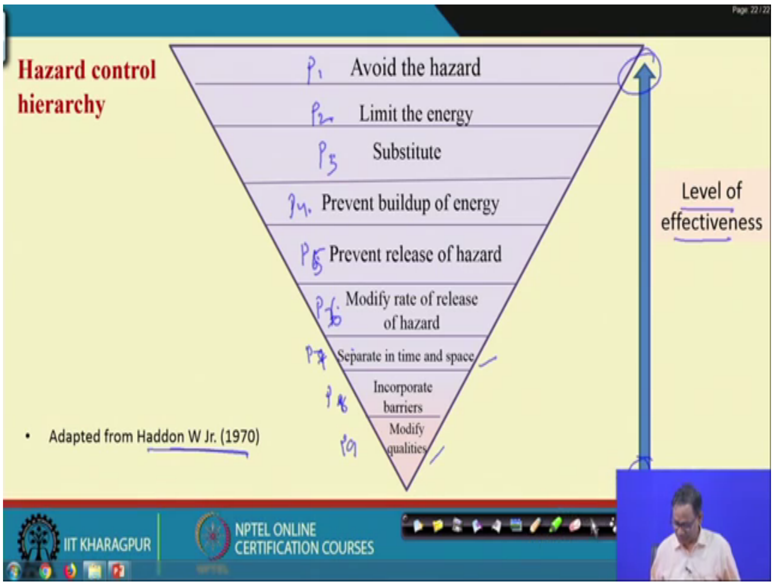


So, yes, you can think in other explain this energy control model with reference to this example so, other way also. But, or the way I am explaining it is quite meaningful and you will appreciate it also. That pumping start non into energy states; so, tank within normal pressure condition that is controlled energy. Now uncontrolled energy tank overpressure condition, you all know that when the overpressure condition will take place we have discussed it several times. Then what happened under overpressure condition opening of relief valve should happen, and operator shutdown of the system that is what is recommended here.

So, what will happen under this situation the? Energy will be re controlled, but at the same time also when relief valve open some of the gasses will go out. So, that mean the controlled dissipation and re controlled again energy re controlled this is possible by this by this protection configuration. So, again that non-zero energy state means. So, long it is working within the timer set time that is under normal condition. So, what will happen that when this operator relief valve and operator shutdown this will fail. So, they there will be ultimately; that means, the controlled dissipation re control of energy as well as controlled dissipation both fails, then the there will be uncontrolled dissipations.

Means, you are not able to bring down the pressure to the designed level, and overpressure condition it will persist maybe pressure one increasing, and understand pressure tank rapture will take place and this lead to damage to the tank to the system to the surrounding source, ok. So, this is simple example, but your plant it will be a huge one. So, you have to understand this with reference to your plant or the system; where you are working or for which you are going to design if you are a student or your an engineer. So, you will do it ok. So, with this concept we will now discuss the hazard control hierarchy. Let us see hazard control hierarchy.

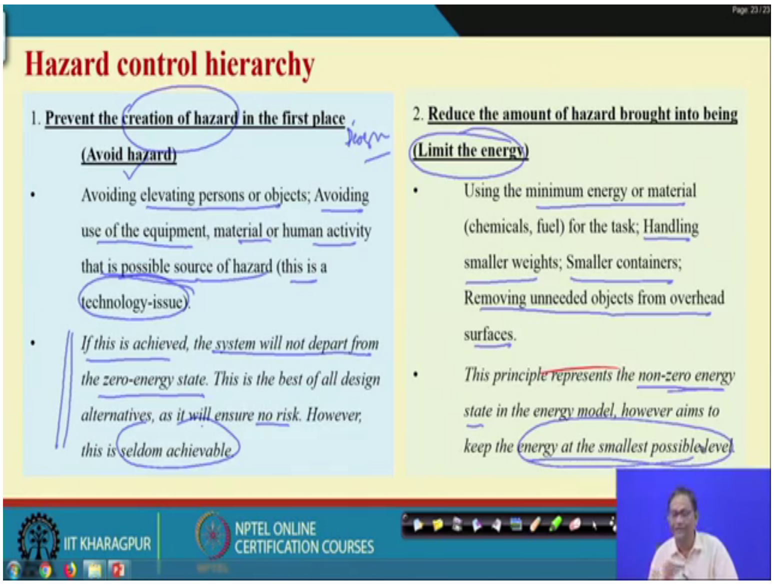
(Refer Slide Time: 13:01)



Hazard control hierarchy this was proposed by Haddon W Junior in 1970. So, you may go through this paper. And he has given 9 that design principles P 1. So, some (Refer Time: 13:20) strategies or principle P 1 is the avoid the hazard, P 2 is limit the energy P 3 is substitute, P 4 prevent build up of energy P 6 prevent release of hazard, P 7 modify rate of release of hazard, P 8 separate in time and space n P 9 incorporate barriers, P 1, 2, 3, 4, 5, 6, 7 it is P 7 P I 8 P 9. So, this is P 5 and this is P 6 so, incorporate barrier and modify qualities.

This is in order of decreasing effectiveness. So, level of effectiveness is maximum here and minimum here. So, if you can avoid the hazard so, the resultant accident scenario from that hazard it will never happen, because hazard is not there. So, that mean if such thing is possible you should do it ok. So, we will see one after another. So, these are the things basically adapted from Haddon junior. We have we have done some kind maybe some little amount of modification the here, and there, but more or less it is basically going as per the principles or the strategies this is given by junior Haddon. So, we will explain now each of the each of the principle.

(Refer Slide Time: 14:55)

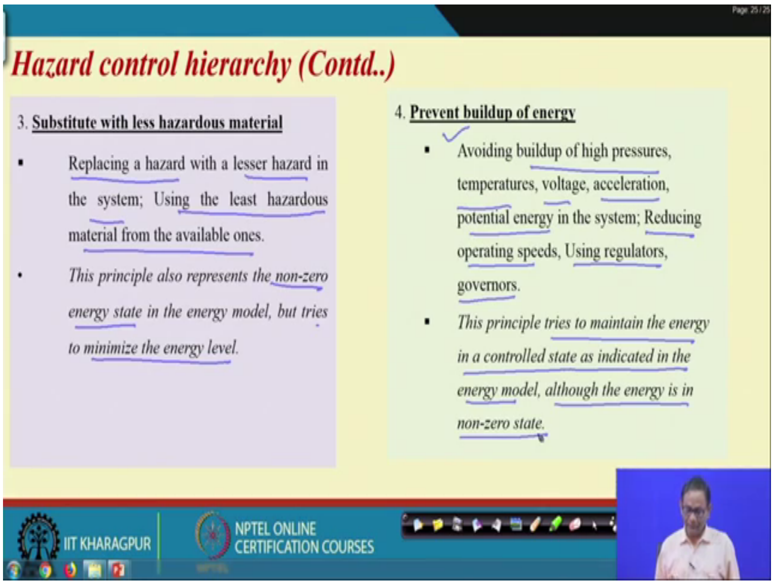


So, let us see that the principle. So, first is avoid hazard, what does it mean? When you are designing something so, you should not create the hazard. You are designing a new system, should not create the hazard, that is basically prevent the creation of hazard at the first place what does it mean during design. So, some example avoiding elevating person or objects; avoiding use of equipment material, human activity that is possible source of hazard this is a technology issue.

So, if this is achieved the system will not depart from the non-zero energy state. That is the energy we will we have linked with energy control model. This is the best of all design alternatives as it will ensure no risk; however, these seldom achievable. So, that mean if this is achievable that mean you in during design you have committed the mistake. Or you have not thought of that or maybe during design that time this technology was not available.

Now, second one reduce the amount of hazard brought into being; that is that I said that limit the energy. So, used minimum energy materials handling smaller weights, smaller container removing and unneeded objects from overhead surfaces some examples given. So, what will happen if you can limit the energy? These principle represent non-zero energy state; however, aims to keep the energy at the smallest possible level.

(Refer Slide Time: 16:44)

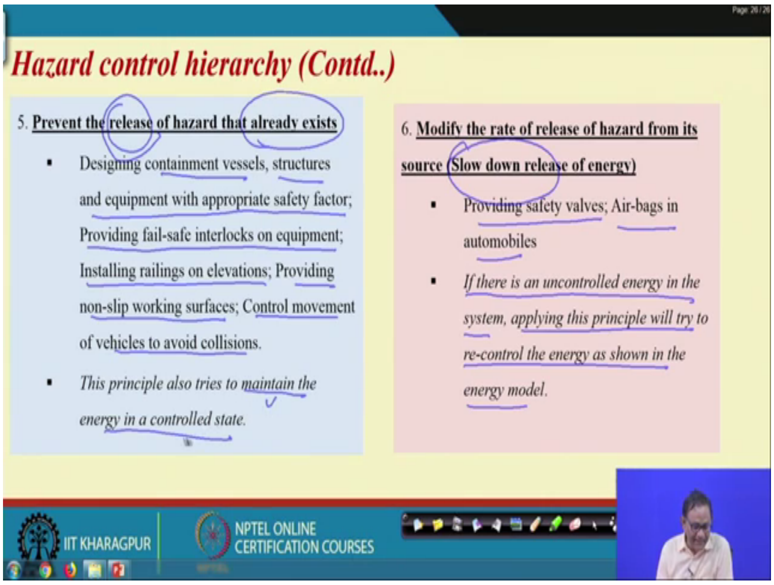


Then later see the third one. Substitute; what does it mean? Replacing a hazard with a lesser hazard in the system; using least hazardous material from the available ones. For example, suppose you are using a nitrogen gas for some work. Argon gas maybe may do the same purpose. So, it is better to use an argon other than nitrogen, because nitrogen is more hazardous, an organ is inner gas so, it is less hazardous. So, what will happen if you do this? This principle also represent the non-zero and, but again it tries to minimize the energy level.

Then the fourth one 4th is prevent buildup of energy, because the first 3 are suppose first three not possible. Then you have to you have to create a system in such a manner that, the building up of energy like overpressure condition should not take place. Like, avoiding build up of high pressure, temperature, voltage, acceleration, potential energy, etcetera. Reducing operating speed using regulators governors all those things, particularly part the pressure tank example, how do you how do you prevent the buildup of overpressure condition.

So, you have seen that alarm pressure gauge, operator and then relief valve operator all those things and timers time set all those things are these. Ultimately, prevent build up of energy. So, this principle tries to maintain energy in a controlled state as indicated in the energy model, although the energy non-zero energy state ok.

(Refer Slide Time: 18:48)

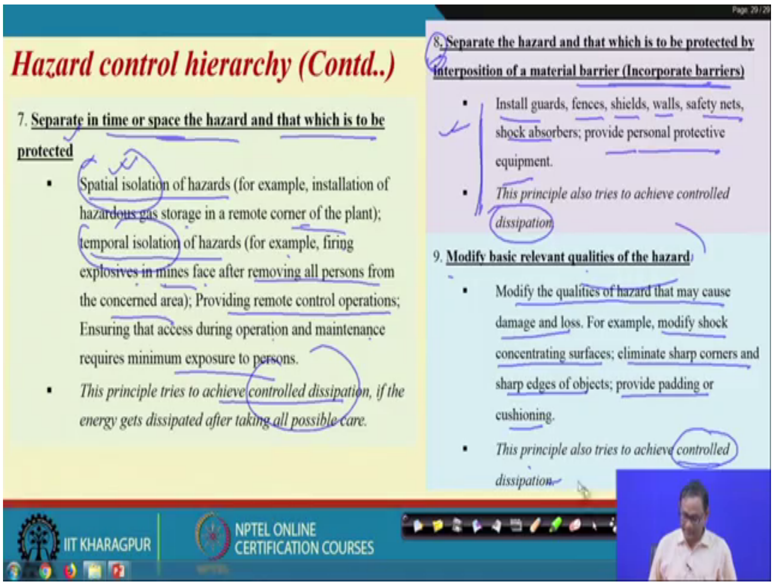


So, now come to the other one prevent release of hazard that already exist. So, let me let me go back one after another. Avoid the hazard most effective. Reduce the amount of hazard brought into limit the energy if you cannot avoid the hazard, go for limiting the energy. Then if there is substitute available it is better to use the less hazardous material. And then suppose first 3 fails, then you can go for buildup of energy should not be there. So, even though you use less hazardous material, that may also lead to build up of energy. So, that means there are some that the mean principle 3, also may be coupled with principle that 4 prevent build up energy that is needed.

Now, come to the 50 principle or 5th strategy. So, we are saying it is principle prevent release of hazard that already exist. So, designing containment vessels, structure and equipment with appropriate safety factor, providing fail safe interlocks on equipment, installing railings on elevations, providing non slip working surfaces, control movement of vehicles to avoid collisions. So, these are the few examples. So, you can add on it. So, what will happen if we apply this principle? These principle maintain the energy in a controlled state within control.

Next is modify rate of release of hazard from it is source; that means, here you are preventing release, here you are slow down you are slow slowing down the release, ok. In P 4 prevent build up of energy, P 6 ok, even if build up it should not be released, that energy should not be released. Then 6, if it is to be released, then it is the release of energy should be slow, ok. So, providing safety valve we have seen that relief valve air bags in automobiles, etcetera. If there is an uncontrolled energy in the system; applying this principle if re controlled energy in the energy model. So, see ultimately up to this up to P 5, what we are saying? That maintain energy in the controlled state, going P going to P 6 what we are saying? That it is basically uncontrolled energy state, and you want to you are basically re controlling the energy.

(Refer Slide Time: 21:59)



After that you have you could not avoid the hazard, but from P 2 to P 6 it is not need not it is not that that P 2 will be sufficient not P 5 will be sufficient. You to understand the layers for how much many layers require, ok. After that what happened after P 6 what happened? So, it is it means what happen that, whatever you do there will be the accident, but it will be in a much reduce scale maybe once in a blue moon.

then even then you required to separate in time and space the hazard that which is to be protected. So, spatial isolation of hazard for example, installation of hazardous gas storage in a remote centre of the plant, this is spatial isolation. Even if something happened it will not affect the people there. Then temporal isolation, spatial isolation, another one is temporal isolation. For example: firing explosive in mines face after removing all person from the concerned area.

Providing remote control operation, ensuring that access during operation and maintenance require minimum exposure of persons. So, this is basically separate the hazard from the target, if you can do this, then this is also an very good hazard control methodology. This principle tries to at achieve controlled dissipation if the energy get dissipated after taking all possible care, fine. So, spatial isolation what will happen? Even though the accident takes place as the targets are not available if I consider human is the target accept the property which basically contain the hazard so, till they will be shift.

So, after P 7 separate the hazard and that which is to be protected by inter position of material barrier in corporate barriers. Guard, fences, shields, walls, safety nets all those thing in fact, we you we most if us understand by safety this, ok. Machine is not guarded properly; so, when working maybe and the scaffold that should be some kind of shield. Or we may say the particular location the material what where work is going on hazard work there will be barricades. So, railway line should be very should be basically should be rail lines so, all those things. So, we and protective equipment, most of the people understand that sorry to tell that including. So, I can say most of us not most of the people most of the most of us an understand safety is this.

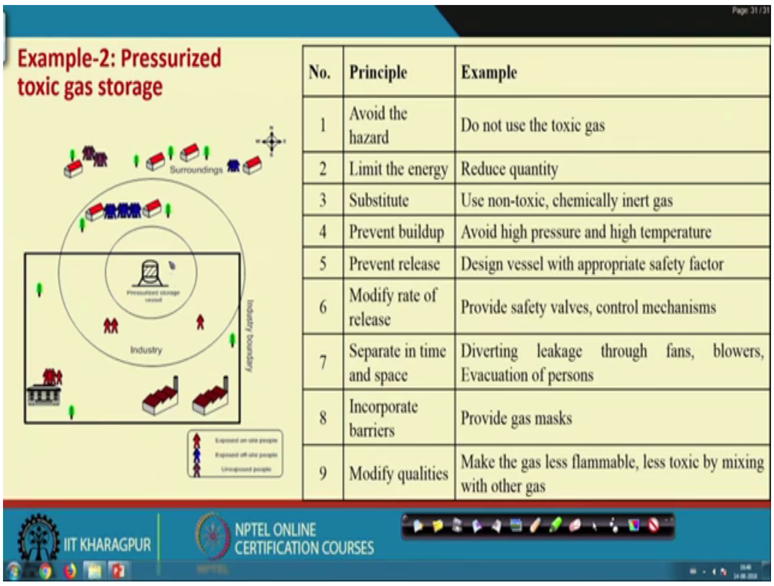
But please understand, as per as hazard control hierarchy it is position is 8h position. So, that mean you have not thought of P 1 to P 7, as a safety engineer or safety manager or a safety professional stakeholder for safety you are thinking that this is my this is my safety requirement. It is not correct, this is required, but previous 7 principles are more important than this. Having the other principle does not mean that you should not have ninth that P 8 it will be there because it is additional it is the almost the last layer.

And then P 9 modify the basic relevant qualities of the hazard if possible. So, modify the qualities of their that may cause damage and loss, modified shock concentrating surfaces, eliminate sharp corners, sharp edges, providing padding, cushioning, something like this, this principle also achieve controlled dissipation. So, you if you see that there are 9 principles we have discussed so far, now P 9 P 9 controlled dissipation, P 8 controlled dissipation, P 7 controlled dissipation. Sorry, then your P 6 re-control the energy. P 5 maintain within control so, that mean, up to P 5 it will it will help you in to operate within the control limit. P 6 that re control the energy. The P 7, P 8, P 9 they are controlled dissipations.

So, ultimately that mean accident has taken place or some undesired is a event then taken place. So, that is why these hazard controlled hierarchy is very, very important one. And please keep in mind that if you really understand the hazards and ultimately the path leading to accidents, and if you understand if you have engineering knowledge, design knowledge that the system knowledge, and hazard knowledge, with the help of hazard controlled hierarchy you will be able to find out the barriers what I can say the protection measures, it may it will be from the prevention as well as mitigation point of view.

And I am expecting that there are many industry professional who may be that going through this particular course. So, for you it is it is wonderful things to you must now apply, and I hope that you all know these things maybe not linking with energy control model, but this knowledge you have now refined it and then you do project and ultimately find out the design and design interventions using this model. Impact in one lecture later, I will show you how it is to be applied.

(Refer Slide Time: 28:21)

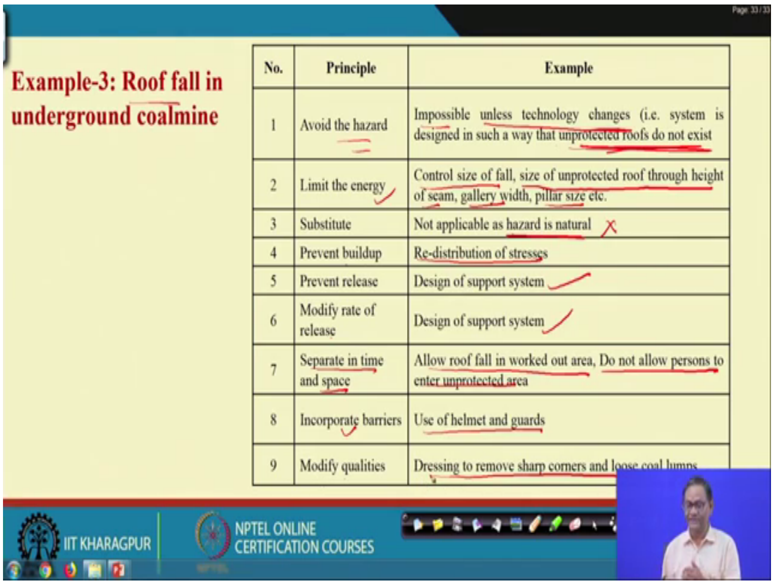


So, with this, I will show you 2 example by 5 minutes of time, that how the principles can be applied. For example, this slide this is a pressurized storage vessel, situated somewhere in the plant. And then we want to apply this principle that avoid the hazard. Suppose, we are saying the toxic gas what is basically stored here this is the hazard. Now the pressurized tank itself is also hazard, but we are basically considering one that gas pressurized toxic gas storage. So, toxic gas if you do not use, then toxic gas related complications will not be there, now limit the energy means reduce the quantity of toxic gas.

Substitute use nontoxic chemically inert gas. Prevent build up avoid high pressure, and high temperature high temperature situation. Prevent release design vessel with appropriate safety factor. So, that what will happen? The leakage the holes in the tank it will not take place; so, release is not possible. Modify rate of release it is, there can be, but there is a limit of the pressure, then you must have the relief valves. So, rate of release will be modified. Separate in time and space diverting leakage through fans blowers, these fans and blowers to another direction that will basically that space wise. Separator and time wise and or evacuation of person; so, that people will not get affected.

Incorporate barriers mean provide gas mask. Modify qualities mean make gas less flammable, less toxic by mixing with other gases, it is ok. Mixing with other gases that may come, but here we are saying that entirely use the different one ok. So, this is one example but, please understand there are many more hazards. We have basically considering only the toxic gas. So, with reference to toxic gas what you will do? That is given here.

(Refer Slide Time: 30:36)



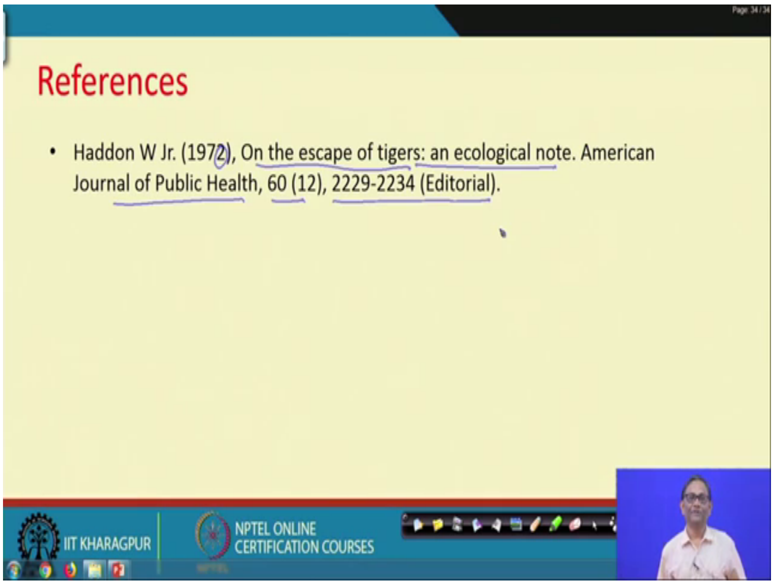
Another one suppose a typical mining case suppose roof fall in mines in mines. So, what is the hazard? Can we avoid roof fall in underground mines? So, yes if there is a technology that will be such the roof fall will be completely eliminated fine. So, but here what happen hierarchy impossible unless technology changes that is the system is design in such a way, that unprotected roof does not exit do not roof do not exists. If you can make it possible, otherwise limit the energy control the size of the fall size of unprotected roof through height of the steam gallery width pillar size etcetera. So, unprotected means if you do some kind of method the change in method design. So, that mean unprotected roof it will be less in the area. So, what will happen? Energy will be limited.

Substitute, we do not know, because this is a natural hazard is natural layer it is impossible, prevent built up the redistribution of stress. So, you know when you create avoid ultimately the stress will be will be distributed to the neighboring solid blocks and if you change the dimensions, again the change in stress distribution. So, you may extract the mine in such a manner that, the redistribution of stress will be in such a manner that it will not it will not make building of the pressure or the roof load; whether it will help in help in; that means, preventing that kind of load which ultimately causes the roof to collapse.

Then prevent release, support system it is obvious support system is there support. Modify of rate of release also through roof support system, suppose if we use the roof bolting, and if you use the timber support and definitely there will be different kind of different kind of impact. Now separate in time and space allow roof fall in the worked out area do not allow persons to enter the unprotected area. In fact, it is in the regulation that it should not be done.

Incorporate barriers use helmet and guards, always you use modify qualities dressing to remove sharp corners and loose coal lumps. So, it is done in mine, but please remember that during dressing the room may fall, and it will ultimately lead to accident. So, dressing is also hazardous job, but if you do dressing with proper precaution what will happen; ultimately the quality of roof will be that will be from damage point of view it will be changed and the impact will be less, ok. So, this is what is the energy controlled model and error controlled hierarchy which can be used in the in the industry to prevent accident protect target or people from accident.

(Refer Slide Time: 33:48)



So, this is what is the reference. Haddon Junior this will be it is 1970, On the escape of tigers: an ecological note. American Journal of Public Health 60, this is this is the editorial part as this from this I have taken, ok. I hope that you enjoyed this lecture. Here what we have discussed, we discussed that safety is energy control. How? Because whatever small work you do, there is energy of one or more kinds. So, if you know how to control the energy, then ultimately you know how to achieve the desired safety.

So, that is why we have given you the principles or the philosophy of hazard control model and the principles behind it. And at the same time with that hazard hierarchy developed by Haddon W junior we linked with the energy control model. And we have shown you the 9 principles and how those principles can be applied in real valve situation. So, this is a very important concepts for all safety engineers. And in later class we will see that use of these in designing safety related intervention.

Thank you very much.