Industrial Safety Engineering
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Lecture – 06
Preliminary Hazard List

Hello, welcome. Today, we will start hazard identification techniques. Under hazard identification, there is the first thing to do is prepare a hazard List, which is known as Preliminary Hazard List.

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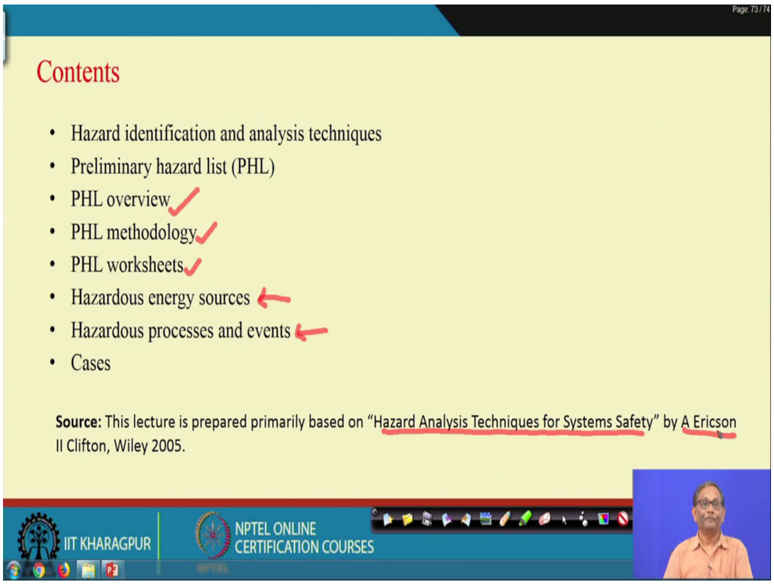

So, the content of today's presentation is hazard identification analysis techniques, preliminary hazard list. So, how to get the list? So, for that purpose, there are few things like preliminary hazard list overview, hazard list methodology, PHL worksheets. And this worksheet will be filled up using information related to hazardous energy sources, and hazardous processes and events and after that two cases will be discussed, so that you will understand that how these total concept of identification of preliminary hazard list will be completed. Again, this lecture has been taken from Hazard Analysis Techniques for Systems Safety by Ericson ok.

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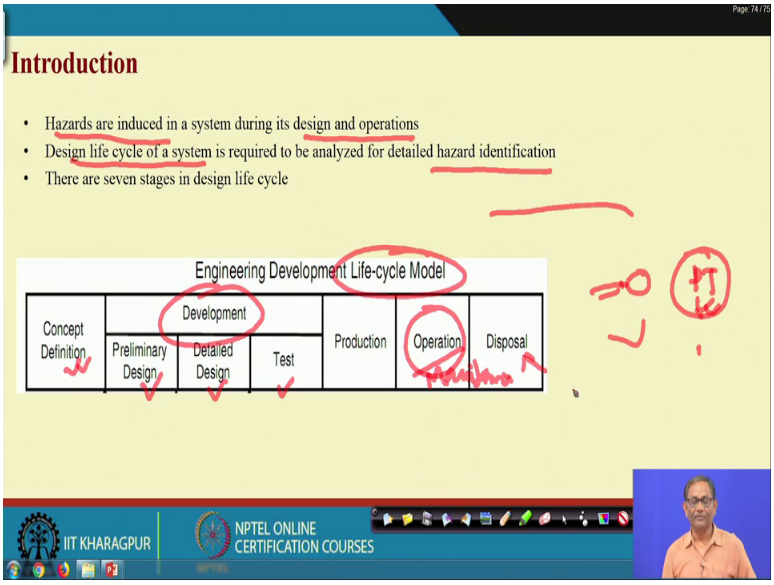

So, here few concepts, one is this engineering development life-cycle model; any product or process gone through the life-cycle of it, being industrial safety engineering the subject so we are more interested in process life cycle. And you just see that when you think of developing a process, first is the concept generation, what purpose it will serve, what is the requirement, who are going to use that invert the customers, the customer requirements all those things come under concept definition

For example, if we think the pressure tank system, what we have discussed earlier. So, and you have found you have seen that there is a pressure tank, there is pump, the total the other part, so now if you think of that who; what is the requirement of this pressure tank, then it is basically the gas at high pressure will be stored, and which will ultimately be distributed to utility equipment, so that means, this is what is the what is to be stored, how much to be stored, what will be the pressure range, and all those things, and who are going to be used. This is what is we are talking about the customer requirement here.

But if we talk of a big plant like going to open this steel making plant or may be a establishing and engineering project division. So, all those things, these are the big things there also you please keep in mind, there is the concept definition means, it is the starting point for any engineering system development.

Then the from the concept definition means knowing the customers requirement other thing so ultimately what will happen, there can be many ideas. So, some of the ideas will be better idea, then finally one of idea will be selected and then the detailed design of this of this product or process will be started by design and development.

And here preliminary design, detailed design, and testing will be done. Once these things are these things are completed, then come the production and operation including maintenance and finally you will think of at the end of the lifecycle the process of the system will be disposed off. So, this is what is the totality in the PtD concept I said that design, built, then operation maintenance, then disposal.

In the same thing and you see what we are talking about that hazards are induced in a system during the design and operation. So, this is a very important part design part; here hazard are induced. Obviously, during operation means, in a each stage also hazard can be induced, but it is the design lifecycle of a system that require to be analyzed for hazard identification.

When you are interested to identify the hazard of a system, you have to first understand the total lifecycle of the system and then you must assume that that hazard will be induced at each stages of this life system lifecycle. And you have to identify all those possible hazards at the at the design stage given in the before the design, so that though the action or protection against the hazard will be build maximally in the design stage ok.

So, now when we are talking about hazard identification techniques we are talking about techniques, which are applicable to the in system life cycle. Some techniques can be applicable to the entire all the stages of the lifecycle, sometimes techniques may be particular stage, but there are the multiple techniques, which are which are developed in the academic and industry arena. And some of the techniques are very popular, and some are extensively used in industries, and some are research type or research oriented having scope for academic development. There are many ways different hazard identification techniques, we will find out.

And ultimately, you have to use those techniques appropriately in the design stage itself ok, so that hazards are identified, and hazards are what I can say protected, prevented to recur or occur, so that people will be protected.

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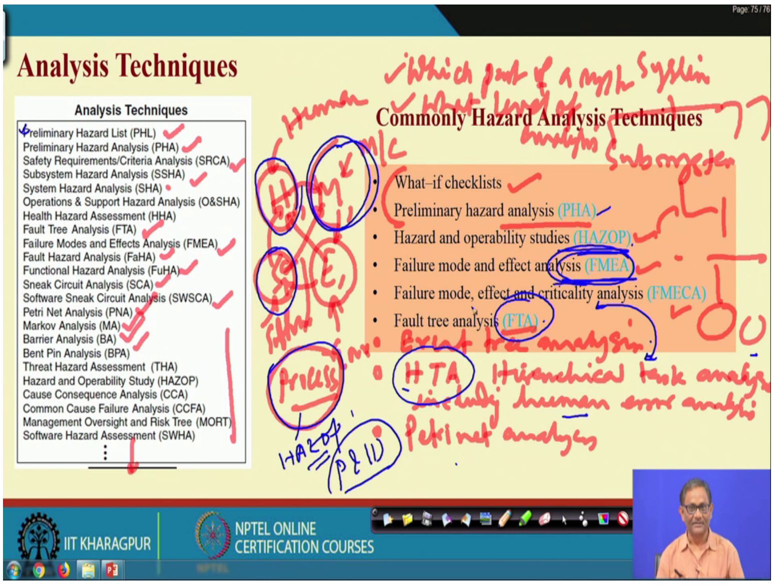

So, let us see that what are the different techniques that are available till now. You see there is lots of techniques, I am naming a few Preliminary Hazard List, Preliminary Hazard Analysis, Safety Requirements Critically Analysis, Subsystem Hazard Analysis, System Hazard Analysis, Operations and Support Hazard Analysis, Health Hazard Analysis, Fault Tree Analysis, Failure Mode and Effect Analysis, Fault Hazard Analysis, Functional Hazard Analysis, Sneak Circuit Analysis, Software Sneak Circuit Analysis, Petri Net, Petri Net Markov Chain, Barrier Analysis, Bent Pin Analysis so many Software Hazard Analysis and super I know that there are more than 50 hazard identification techniques already available in the later region.

Why such a huge number of techniques, the region is in the context of its application. So, some techniques are applicable in the particular context in a particular design stage of the system lifecycle. And the commonly used techniques what I have come across so far I have seen that what if checklist is heavily used; preliminary hazard analysis is used, HAZOP, failure mode and effect analysis, failure mode effect criticality analysis, fault tree analysis, and then event tree analysis, event tree analysis. So, these are the few things used mostly.

And other techniques like your Hierarchical Task Analysis HTA, which is Hierarchical Task Analysis ok, and in a including human error analysis, including human error analysis is another important one. And from software engineer an hazards point of view petri net is used petri net analysis.

So, the logic behind so many analysis techniques identification analysis techniques, I told you that; you just think of a system engineering system, you will find out that the system comprises of human, then machine, environment, software. So, human, machine, environment, software, obviously there will be interface between them, so interface between them will be there ok.

So, now what are the techniques, which are applicable to machine related hazard analysis, then a environment related hazard analysis, software related hazard analysis, human related hazard analysis. You think of a boiler, there is a process going on, you think of a chemical reactor some process going on, so that mean, that there will be another one is there, one the country category is process. So, what are the technique that will be used for process hazard analysis.

So, second thing is that a system will be composed of several sub system; system to sub system several subsystem, then several sub system, then finally the components will be coming. So, a system will be composed of several subsystem and finally lot of component all those things. So, you may be when we are talking about the hazard analysis, the obviously the first thing is the system hazard analysis, so that mean now you can go by system breakdown structure.

You find out the system components by system, subsystem, sub system process component level breakup, and then at the component level find out the hazards, then at the sub system level find out without hazards and sub system level hazards, and finally aggregated all will give you the system level hazard ok, so that means, at what level of analyze hazard, hazard identification, and when is this you are doing that also dictate what kind of technique you will be using.

So, that mean essentially what I mean to say that it is that the which part of the hazard is considered which part of a system and second one is basically that what level of analysis you want level of analysis you want. And depending on the two, what will happen, you will choose. For example, what if an preliminary hazard analysis, these are very much used for any kind of things like human, machine, environment, process, it is may be at the total system level or may be at the component level it is possible.

Hazard and operability studies, it is mostly used in process industries HAZOP. Failure mode and effect analysis, which mostly used for machine and equipment related items. Fault tree analysis, when you want to dig down to from the top level events to the basic events, means suppose system level failure to the component level causes, then like system breakdown structure there will be the system failure also will be understood through different (Refer Time: 14:36) analysis with grade gates and symbols that will give you fault tree. So, fault tree actually take high level analysis, it can be applicable to everything.

Event tree, fault tree, then HTA, and human error that human hazard analysis; petri net for software hazard analysis. So, when you think of that environment contribution that an environment related analysis. So, off let what happened that there have been development by which that some of the techniques, which are originally developed for a in a particular context, they are expanded to other context or other situation. For example, the HAZOP can be used in maintenance also, so that is known as maintenance operability studies. So, in that sense, that is why that so many hazard analysis techniques are there.

We are not able to tell you all the techniques, but some of the techniques we will be discussed. And today in this particular lecture, I will be discussing this preliminary hazard list. So, keep in mind, there are multiple of techniques those are known as hazard identification techniques, sometimes which hazard analysis techniques also, but whatever may be hazard identification in the first stage, then followed by hazard analysis.

And in any system there will be there will be either process, it can be a chemical type continuous process, can be a discrete type process also. So, there will be set of several equipment for machines, there will be there they may be software control may not be software control, so there will be people that means, human intervene system or subsystem or component or may be automated or semi-automated system, subsystems, and components.

So, depending on where you want to concentrate if you are concentrating on human error, it is better you follow a hierarchical task analysis, followed by any of the human error analysis techniques. So, we have some lectures on human error analysis in the later stages. Similarly, if you are interested to know most of the equipment type of hazards like your palm, moto, conveyer system, so then for this failure mode and effect analysis will be a better one.

If you think no your system is process oriented like a chemical, like your petrochemical industry, like oil and gas industry, like in even in steel making, there are different kind of continuous processes are there; where the process parameters are known, and they are designing (Refer Time: 17:34) are known and the they are designed in that manner. So, and through piping and instrumentation diagram P and ID P and P and ID that the total system can be explained; under such situation HAZOP is wonderful.

So, this PHA or PHAL, PHA, HAZOP, FMEA all those things basically are they can be applied at the system level also subsystem level, so but depending on the quantum of the system if it is a very large system, it will be intractable. So, you have to break the system into subsystem to component level and then apply.

By saying this I am not saying that you do not go for other techniques, you may go for other techniques, there are recent many techniques gradually are being developed, but this is a guideline. So, my guideline is when you are dealing with a process, where the pressure, temperature, flow current, and all those process parameters are available there design intent are known their operation details are easy to are capture. So, I think the process deviation parameter deviation will be a better measure; go for HAZOP.

Suppose you are dealing with a conveyer system or a crane or any discrete machines like a in the workshop, what we see, then it is better you go for failure mode and effect analysis ok. Suppose you want you have done the PHA, HAZOP, FMEA at the at the may be system or subsystem level and you want to further dig the you found out the top level or level accidents that can happen from this analysis. And you want to further dig down to the root cause level for this fault tree analysis will give you wonderful result ok.

So, this is the basis for why so many techniques are developed and you find out which of the techniques will be better suited for your system, for your subsystem, for your component. Even component can be further broken into parts to identify the failure modes ok, I think it make some sense.

So, let us go to preliminary hazard list. So, first what I will do, I will give you the steps what way you will do, and then with example I will show you that how I will demonstrate the steps, and then finally what is that you have to develop your own case ok. I do not know your background, because from which discipline you are coming from, but please remember the domain knowledge is very important. So, the techniques and the examples I am giving to you, where technique is domain independent, but the examples are domain dependent. It is not that I am taking example from all the all purposive sectors all industries; it is basically a particular some in industry problem we will be discussing.

But if you are suppose you are from a civil engineering department civil engineer, then you have to find out a civil engineer domain where you are going to use this technique. And accordingly, you have to translate you have to use this domain independent technique into your domain, based on examples at a guidelines thank you.

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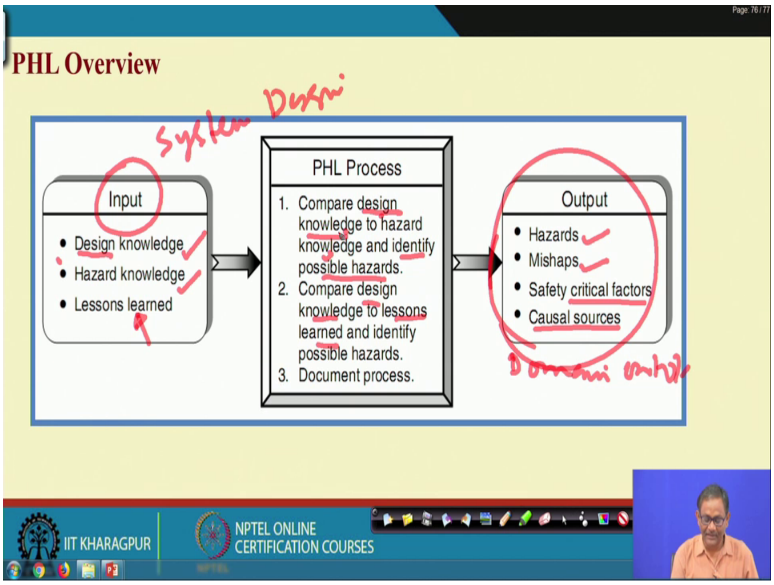

Let us see that what is what you require to know for doing PHL, please understand design knowledge. By design knowledge what I mean to say, you must know the your process or the system better word we will be we will be using the word system, because it encapsulate everything. The system breakdown up to component level parts level, the function that each of the components will perform. The interdependency between the components; then subsystem versus sub subsystem, system versus subsystem, the cross-functional dependencies all those things. Then what are the parameters that are applicable, what are the design intent, are you in a in a can you just represent it schematically, when operation starts, how it starts, what are the operational sequence. So, what are the all those things operation maintain all those actually things how it will performed, those will come under design knowledge.

So, design knowledge is very important. If you do not have the system knowledge of system, system design, then you cannot break it up to component level. And if you do not know the component level functions, the subsystem level function also you will not be able to understand, so that is design knowledge it is a first thing. But if you are a mining engineering, then I understand that you know the methods of that mine design, maybe it is underground open (Refer Time: 23:38). If you are a metallurgical engineer, and working in a glass in a steel plant, I am sure that you know the design have blast furnace ok.

(Refer Time: 23:49) if you are a mechanical engineer and handling the may be the overhead cranes in a factory, then I am sure that you have the knowledge of crane, so that is what I am saying that that design knowledge is you must have. Apart from design knowledge, the second thing you must have is the hazard knowledge. By hazard knowledge, what are what is hazard, and how hazard is ultimately converted to accident through different initiating mechanism, all those things we have discussed so far.

So it is now imperative to say that you are in a position to till know that what is hazard. And after going through all the techniques, you are the definitely the hazard knowledge will be improved, but at the basic level, whatever I have discussed so far that that you must have. And you must be able to understand what are the hazardous sources, that is hazardous elements, and how the hazardous sources will ultimately occur through different initiating mechanisms and then finally target and threat so those concepts here for the domain, where you are working in, so that is important hazard knowledge.

Another important one is the lessons learned, that the system for which you are interested in designing ok. So, there what you will find out you will find out that a sim system similar system, it has been operational for since long, and there have been many incidents are takes taken place or many inspections, were carried out. So, as a result, a good set of vocabulary is available with you, the data is available with you.

Maybe you have already designed similar system and or some the company having this or then what will happen ultimately. So, when you are talking about design knowledge, already you have learned from your previous design, so that is also lessons learned. So, all those things you must have. Unless you have these inputs, it is very difficult for you to do any kind of hazard identification, and as such safety engineering will be impossible for you ok. So, as a result, you all will agree with me that it is not a independent work, it is a team work; and the team comprises may be design people, operation people, maintenance people, safety experts, analyst, so many ok.

So, what will be the output, output will be hazards, mishaps means accident, what are the safety critical factors and causal sources. In other sense, I can say this will give you the safety domain ontology will be where data safety either through this inputs. I am sure that from hazard earlier target threat, the domain ontology domain ontology you will be able to repair; that is what is my outputs.

So, how do it, what is the process, process is your design knowledge will be compared with hazard knowledge, and then identify possible hazards. Design knowledge will be compared with the lessons learned identify possible hazards, and document process, so that means, hazard knowledge and design knowledge will be compared; design knowledge and lessons learned will be compared. So, these two will be compared and these two will be compared and you will be finding out the gaps, and then you will just continue.

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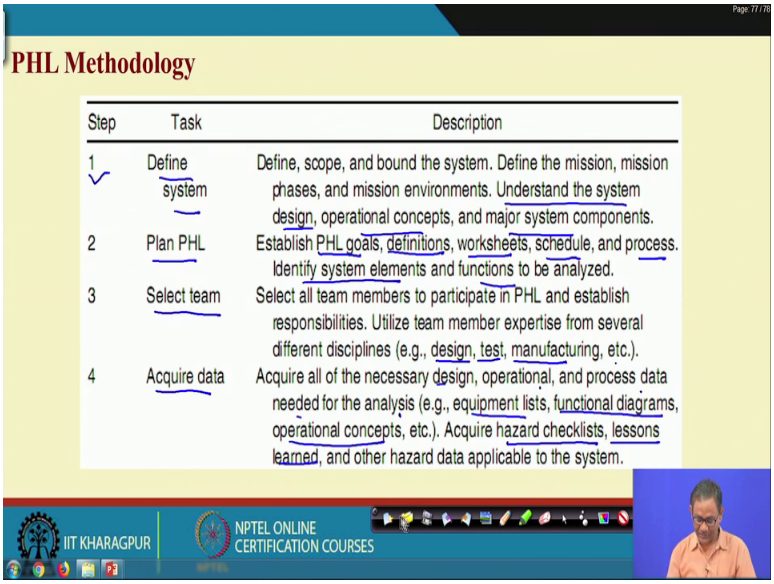

So, what is the methodology, methodology it is a first is step 1, define the system. So, define scope build the system. So, it is basically your knowledge about the system, understand the system, design operational concepts, major system components, I told you already. Then plan for PHL, what is the goal, you define worksheet, schedule, process, identify a system element, function to be analyzed. And once you have define the system, then system specific goals subsystem specific goals you may be interested to know only the high severity accidents, then that will be your PHL goal.

You mention no I do not want to leave anything left, so detailed goal is discuss. Then select team, if you do not have team, you can do it. (Refer Time: 28:49) discipline, design, test, manufacturing, so different discipline people must be there. Then this team will acquire data. Acquire all necessary design, operational, process data needed for the analysis, equipment list, functional diagram, operational concepts, hazard checklist you find out, previous lessons whatever learned, all those things you bring, then only it is possible.

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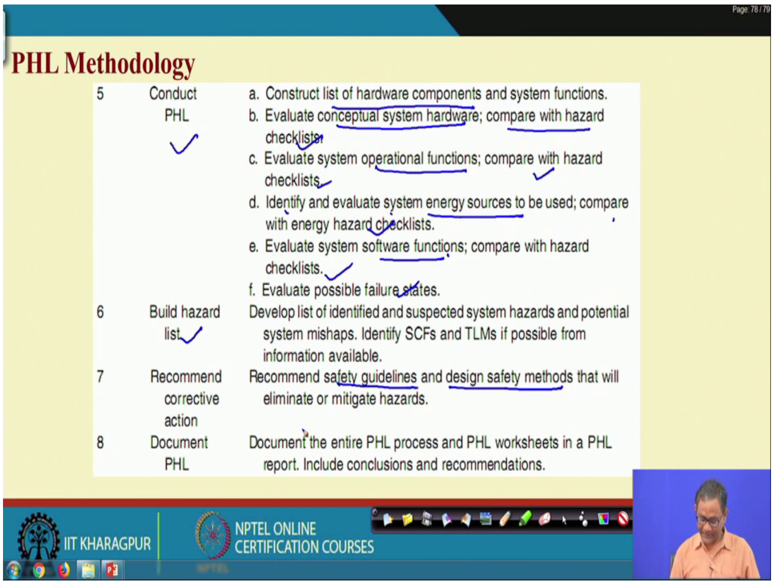

So, after that what happened, once you have the data conduct PHL. In PHL, what you do, construct list of hardware components, evaluate conceptual system hardware; compare with hazard checklist, operational function; compared with hazard checklist, then identify and evaluate system energy sources; compare with hazard energy hazard checklist, evaluate system software function; compare with system hazard checklist, evaluate possible failure states, so that means, as I told you that there will be component, there will be your software ok, so you have to there will be different hardwares. So, all those there are different functions, so that that specific design knowledge you have, you have hazard checklist, and then compare them, and find out this.

Then what will happen, once you do this, you will have a hazard list. Now, hazard list, then recommend safety guidelines and design safety methods and then document, so this is what is the process.

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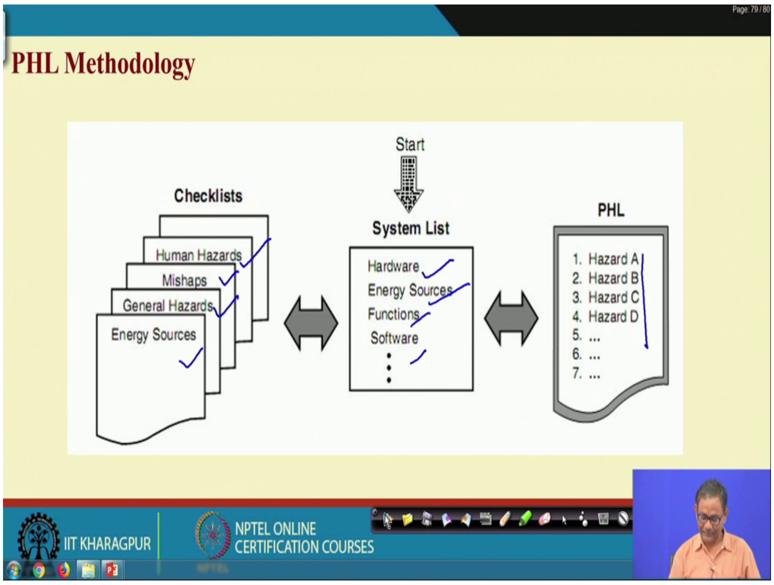

So, methodology checklist you require you require checklist, human hazards, have different accidents, general hazards, energy sources. Then what is the system list, there will be hardware, there will be different source, function software and different kind of hazards.

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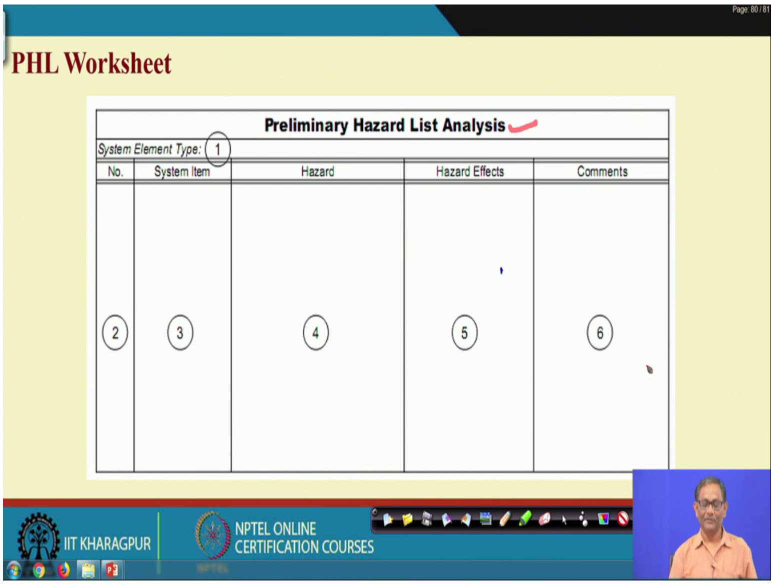

Then you have a documentation table; the table is like this. You see preliminary hazard analysis, system element type what kind of (Refer time: 31:13) it is a equipment, it is a process, whatever maybe. Then you number them, then what item name system item name you write, you write what are the hazards, what are the hazard effects and comments ok. These things you have to prepare; this is what is hazard list.

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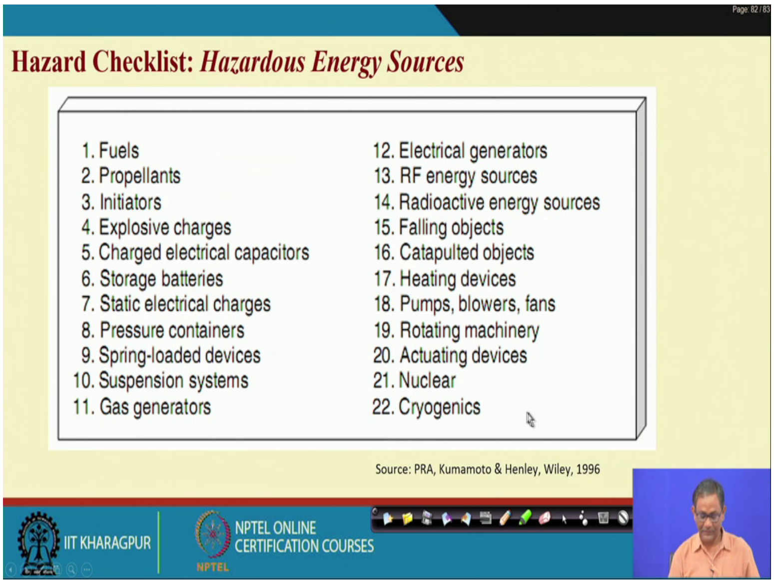

I will give you one example, and before that I said that you must have the hazard checklist, here we are basically looking into hazardous energy sources, you see that starting from fuel, propellant, to nuclear and cryogenics. There are 22 energy sources; I have taken this from this book Kumamoto and Henley probabilistic risk assessment.

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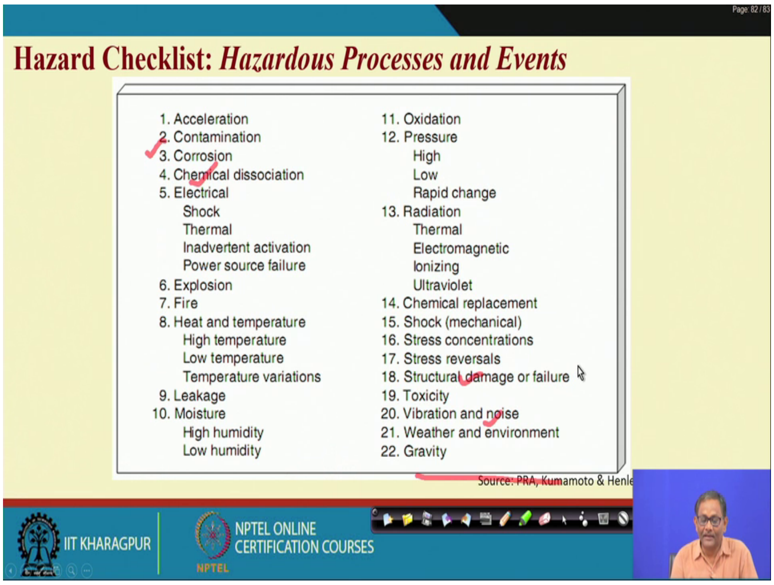

Similarly you will find out that there are different hazardous process and events, it can be acceleration, can be contamination, can be corrosion, so that means, you require to have checklist; the checklist related to everything. And then, design knowledge will be compared with hazard knowledge, and design knowledge will be compared with lessons learned. And follow the checklist, find out the gap, document it. And the documentation from I have already given to you. It is it is a very much you domain knowledge specific.

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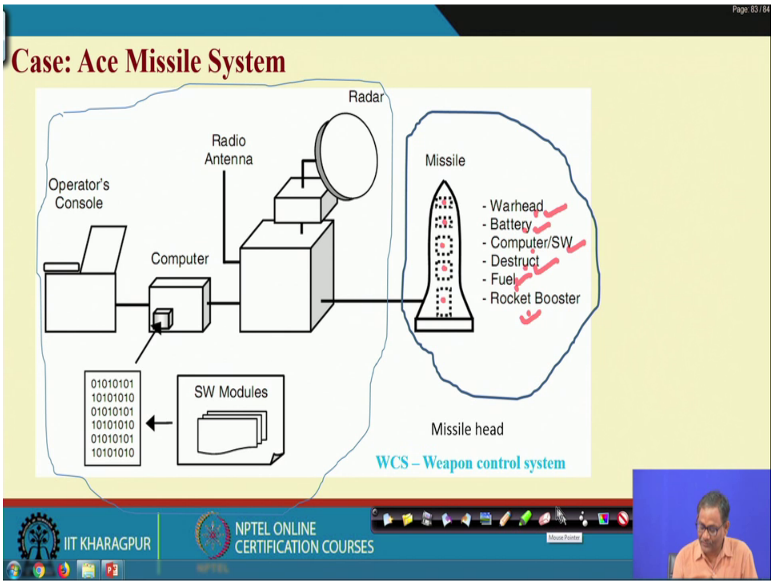

Let us see this; what is this? It is ace missile system, weapon control system and then missile system I have taken this from the Ericson book. So, suppose this is the total system ace missile system, it is two subsystem, weapon control system is this and this is the weapon missile. Now, again if you if you further breakdown the missile, there will be warhead, there will be battery, there will be computer, destruct, fuel, rocket boosters. So, these many components are there 1, 2, 3, 4, 5; 1, 2, 3, 4, 5, 6 ok. So, these similarly if you see this one, this can be further broken down also.

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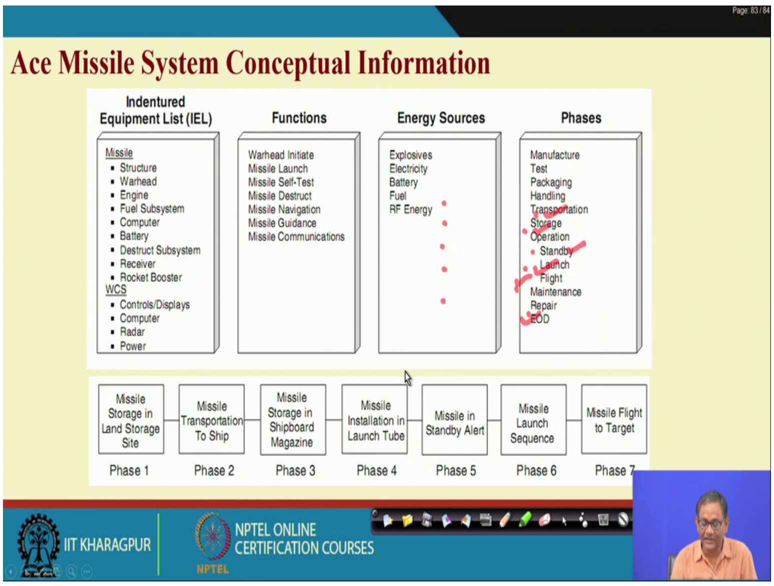

Now, what is required, if you want to really do a you must know not only this, you must know this what is this, you see intended equipment list the missile is all components weapon that control system, component. What are the functions, what are the energy sources applicable, and what is that stage different stage. So, and when you basically talk about missile launching, you see that there are different phases that is what I have we are saying the system knowledge.

You take your own system, are you able to break in this manner or not. If not, then your you are not you are not fit to do it, then definitely you see that you in the team somebody will see there or not. So, you make the team in such a manner that, they will be able to do it. So, missile launch is missile storage in land storage site, missile transportation to ship, missile storage in shipboard magazine, missile installation in launch tube, missile in standby alert, missile launch sequence, missile flight to target. This is the different phases. How the PHL is used, just I am showing you.

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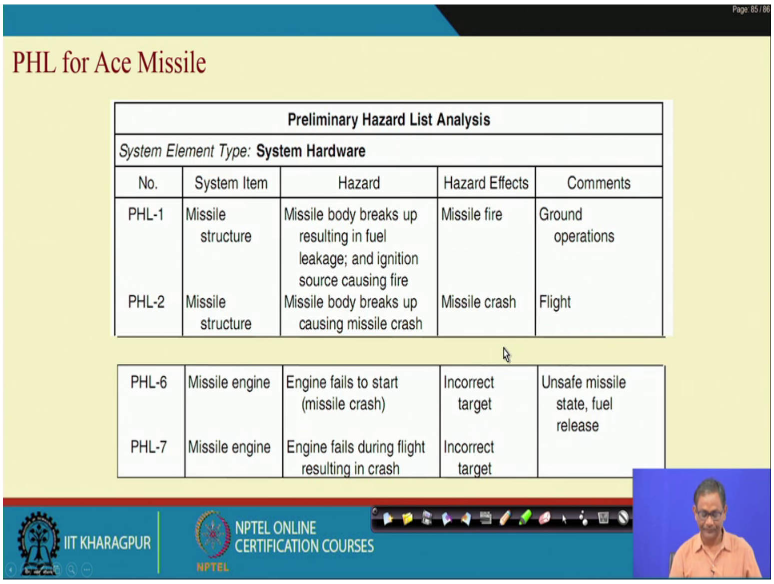

The documentation part; you see system hardware is the system element type, I think you are first going to hardware then software, human error, environment so many things will be there. So, hardware system missile structure, this is my list one. What are the hazard, missile body breaks up, resulting in fuel leakage; and ignition sources causing fire, then hazard effect is missile fire. So, the missile body breaks up resulting in fuel leakage and ignition so that means, hazardous elements and initiating mechanisms have told you.

Missile body because missile structure is the hazardous element. What will happen, it will breaks up resulting in what if this once this breaks up fuel leakage ignition source then fire will take place fire who are target definitely the people and the property. And comment means in which operation starts type in the ground it is happening.

Similarly, the same system element missile structure will be having another list. Missile body breaks up causing missile crash, so causing fire and another is causing crash, missile crash during flight. In during ground operation, this will take place; during crash, this will take place. So, in this manner, once you go so one so one hardware to another hardware like missile engine, then engine fails to start incorrect target, unsafe missile state, and fuel release; this is the comment.

Missile in engine fails during flight resulting in crash, incorrect target. So, you have to to prepare a list like this. So, what will happen, once you com you take all the system element type from hardware to software to human error ok, when one entire system break down structure you make and find out all the system items. So, for every system item, you may have one or multiple hazards. And all those things once you list for a system, it may be hundreds of hazards will be there, so that is important that list we want to find out. So, for the system, there will be many more hazards, but I have shown only this only 1, 2, 3, 4, but the list is very long. I request all of you to go through this book written by Ericson and you will find out very interesting book and lot of lot of lot of explanations are also given for this.

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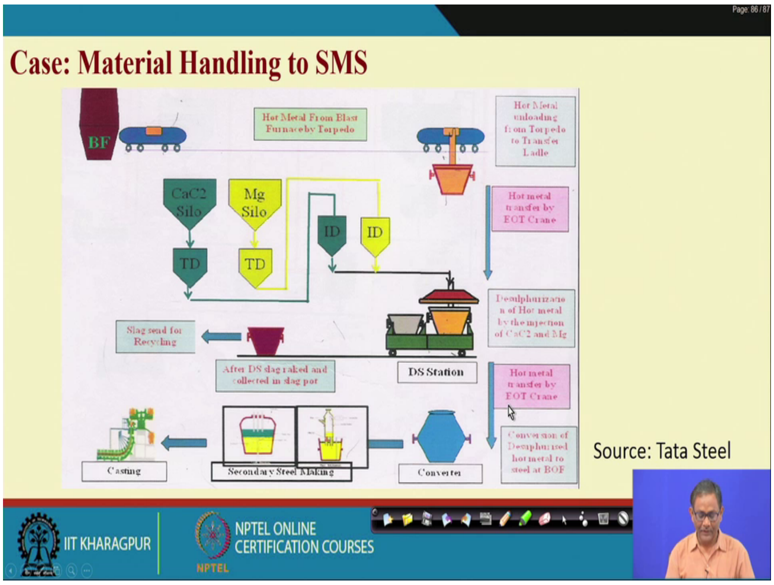

Now, I will give you an case what we have done it is a basically material handling case in steel melting soft; otherwise I can say steel plant there is from blast furnace through torpedo hot metal from blast furnace by torpedo, hot metal blast furnace liquid metal very hot more than 1000 degree centigrade here, so that what will happen hot metal from blast furnace with torpedo, it will come here. And then there is a transfer lead a hot la metal unloading from torpedo to transfer ladle. Then hot metal transfer by UT crane will transfer this to desulphurization unit; desulphurization of hot metal by injection of C a C 2 and magnesium Mg that is the happening here.

And then what happen after desulphurization that slag will sent for recycling, but the desulphurized hot metal will transfer to by EOT crane to converter that is (Refer Time: 38:56) soft. So conversion of desulphurized hot metal to steel to that BOF ok; so basic oxygen furnace. So, then further, so this is what is the total that hot metal handling in a steel plant, so that other one that is a crane is EOT crane is used.

Suppose we want to do the preliminary hazard listing for this, then what you require to do with reference to material handling you must know what are the components or what are the different system it types first hardware based if you getting more mostly of hardware type. So torpedo, ladle, then crane then definitely the desulphurization and SMS. So, all those things and SMS and this there are some process is taking place there will be obviously, when you talk about crane operator is there are software also in between some program we will control ok. So, for the time being I will just show you we will suppose torpedo what we what way we can do this.

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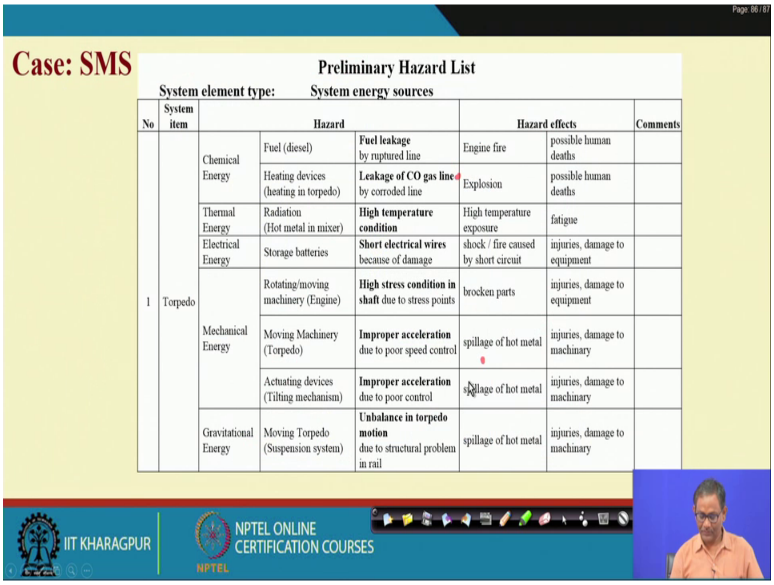

No	System item	Hazard			Hazard effects		Comments
1	Torpedo	Chemical Energy	Fuel (diesel)	**Fuel leakage** by ruptured line	Engine fire	possible human deaths	
			Heating devices (heating in torpedo)	**Leakage of CO gas line** by corroded line	Explosion	possible human deaths	
		Thermal Energy	Radiation (Hot metal in mixer)	**High temperature condition**	High temperature exposure	fatigue	
		Electrical Energy	Storage batteries	**Short electrical wires** because of damage	shock / fire caused by short circuit	injuries, damage to equipment	
		Mechanical Energy	Rotating/moving machinery (Engine)	**High stress condition in shaft** due to stress points	brocken parts	injuries, damage to equipment	
			Moving Machinery (Torpedo)	**Improper acceleration** due to poor speed control	spillage of hot metal	injuries, damage to machinary	
			Actuating devices (Tilting mechanism)	**Improper acceleration** due to poor control	spillage of hot metal	injuries, damage to machinary	
		Gravitational Energy	Moving Torpedo (Suspension system)	**Unbalance in torpedo motion** due to structural problem in rail	spillage of hot metal	injuries, damage to machinary	

So, see system item is torpedo; system item is torpedo. Now, hazard this is additional thing we have added, but from here you can see hazard that fuel, fuel leakage then what are the hazard effect the engine fire, possible human deaths. So, in this manner, in this manner, several hazards are identified that is what is the listing of hazards. So, to make it each of identifying the energy different kind of energy are consider like chemical energy, thermal energy and mechanical energy, it all depends on your knowledge you can do. So, the basic documentation frame work what I have given that is fine.

But apart from this also you can argument it there is no hard and fast rule that that will be used, but please keep in mind the hazard element, initiating mechanisms, target and threat the entire path that must be completely enumerated for every system item, there will be multiple such hazards. So, here 1, 2, 3, 4 like this so many hazards we have identified. See, this is torpedo, then ladle and crane converter so many things ok.

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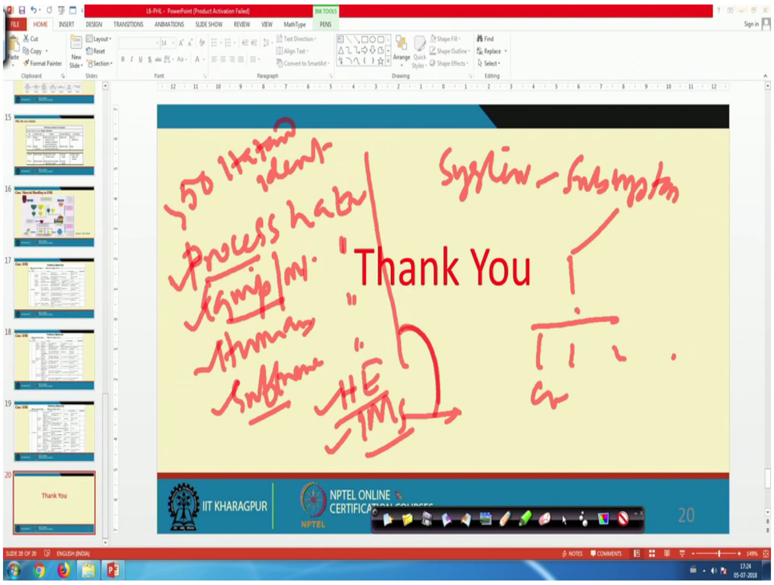

So, let me conclude what you have learned here that we say that there will be different techniques more than 50 hazard identification techniques are available; hazard identification techniques. It is not that all techniques are applicable everywhere. Broadly, there will be process hazard, there will be equipment on machine hazards, there will be human hazards, there will be software hazards, these are broad things these are important.

So, you have to and another important one is that system knowledge. So, system to subsystem then sub subsystem are finally, may be the all the components, this structure is very, very important. So, there in the system, there will be definitely hardware point of view then process, equipment, software point software will be there human will be there you have to first identify maybe you do this kind of breakdown and finally, at the compound level you come. Otherwise, you can do also suppose you consist the hardware find out that that every hardware item how it fails what are the hazards avail available there. So, what are the hazards there then it is better to have the checklist.

So, mostly in large plant with high risk the energy is very important one, there are energy sources, starting from gravitational energy to high level energy like your explosive all are available there. So, all hazard when you take a hazard a system item and compare with the energy sources, you first see that what kind of energies are source there. And then if you have the functional knowledge of that system item and you if you know that how that system item is interlinked with other system items also, so then what happen the you are in a position to find out the initiative mechanisms.

Few initiating mechanism related to the system item only, but few are dependent on may be other things, but whatever may be the thing, the system item one identified then the all the hazard using hazard checklist and hazard energy sources you will be able to find out the identify the hazardous elements. And using the hazardous process and elements, the initiating mechanisms can be identified. And obviously, because of your the system knowledge and operational knowledge, you will be in a position to know what is the target and threats.

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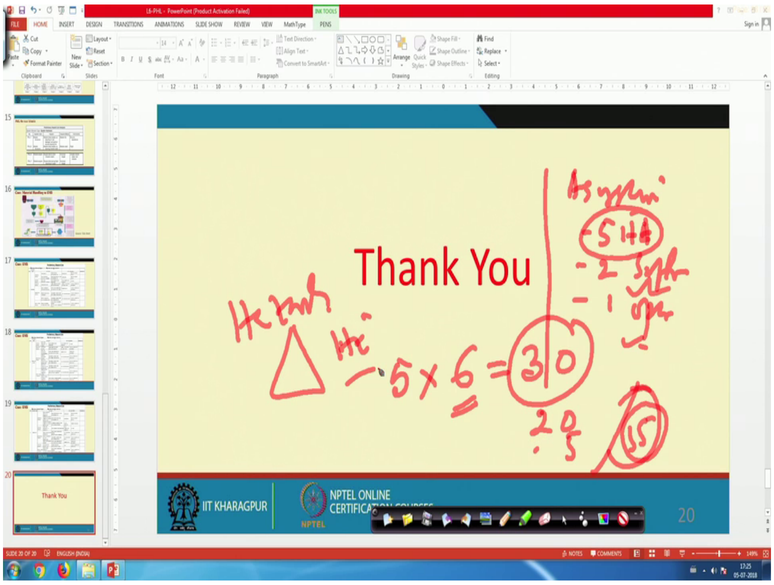

So, once you do this, then your hazard list is ready. For example, suppose I take a system ok, there are suppose 5 hardware item; suppose 2 software and let it be 1 operator. So, a 5 hardware item may be every hardware item there are let be 6 number of hazards, so that is 30, it not be everything and since someone 5, someone 6 like this the 30. For 2 softwares, you may get another 20; for 1 operator, you may get another 5. So, many be 55 hazards you will find out.

By hazards 55 hazards, I am talking about hazard triangle. So, 55 hazard triangle, you can develop ok so this is what is hazard list. And I hope that it make sense and because we have shown you two cases also, if you are not able to understand, you just repeat the video and go to the case again pause there, and see that what is written in this way you will definitely learn the hazard list, ok.

Thank you very much.