Industrial Safety Engineering
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Lecture – 09
Failure Modes and Effects Analysis 9 (FMEA) - Identification of Failure Modes

Welcome today we will discuss Failure Mode and Effect Analysis this will take some time it is not possible to complete by half an hour. So, it will require more than 1 hour. So, that is why what happened today in next 20 minutes of time I will just discuss that what is failure mode, and how to identify the failure modes. And obviously, the methodology for failure mode and effect analysis I will give you one example.

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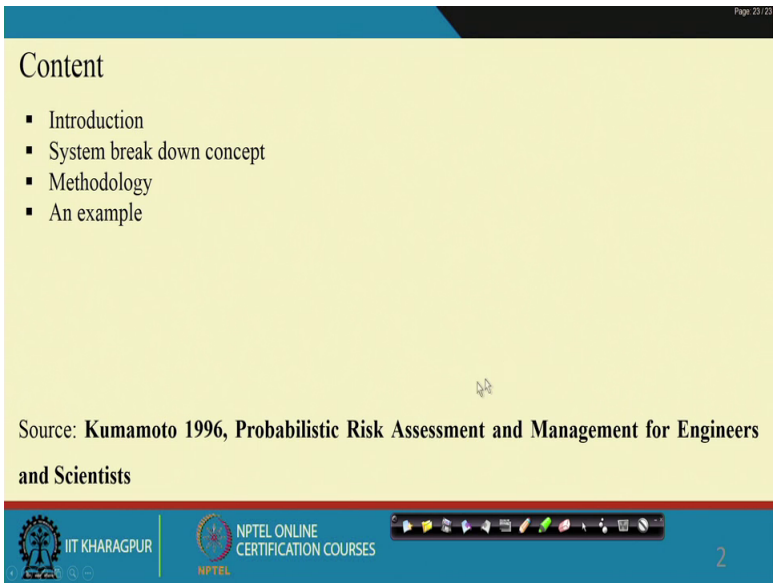

So, the source is ded probabilistic risk assessment by Kumamoto and Henley, and a I will show you one example that example we have taken from the net internet source.

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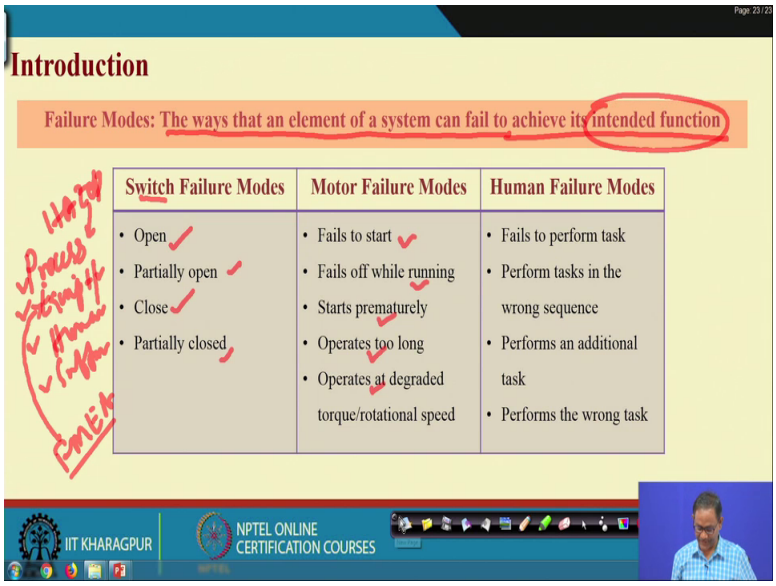

And just could not find out the, this one the exact source, but this is a very good example. And we will try to find out figure out where from it has come from and then we will definitely include add here and we will mains up. So, now what is failure mode failure mode and effect analysis is very, very important hazard identification and analysis technique, which is used very much in particularly in equipment failure case. So, if you recall my earlier lecture I just told that that hazard can be process related, hazard can be equipment hazard or machinery, hazard can be human hazard, software hazard so like this.

Now, if I say process means a continuous process kind of things if hazop is king in this case. Then for equipment and machinery related that hazard analysis case FMEA is a is the king not the queen. By saying this I am not saying that FMEA will not be used under process or human or software cases or vice versa that as if cannot be modified to you in equipment related analysis. It is possible, but more often what happened we use FMEA when we talk about the equipment related hazard analysis or hazard identification.

Now, in failure mode and effect analysis one of the important concept is called failure modes. So, we will slowly while fist discuss failure modes then go we will go slowly to the effect and the causes and finally, the methodology or procedure that will be adopted to conduct the failure mode and effect analysis into this lecture.

Failure modes, mean the ways that an element of a system can fail to achieve its intended function. Please keep in mind that intended function is very important one every time we are saying, because either a system subsystem or component whatever we have basically developed these are these are for certain purposes. So, that is what is the intended function even a component for a valve it has intended function. So, now, valve can fail, a switch can fail, a motor can fail, human fail. So, there are like process fail, equipment fail, human fail, software fail. So, everywhere there is a way it will there is a different ways it will fail ok.

So, every way is a mode, so that is why the ways and element of a system can fail is the failure modes for example, switch all of you know electrical switch. So, switch you want to close it, but it remain open that is also failure more another on the other hand suppose you want to open the switch, but it is in close mode. So, similarly some impartially open partially closed may be something more you can add here. Now motor, motor fails to start fails off while running starts prematurely operates too long operates at degraded torque or rotational speed this is the from motor failure mode. If you say pump it will be similarly pump failure motor is also similar because pump itself is a motor.

Now, human failure mode human fails to perform a given task, perform task in wrong sequence perform some additional task performs the wrong task. So, perform the wrong task you are asked to you are you are asked to clean the floor and suppose you have you have cleaned the outdoor instead of the in floor indoor. So, something like this wrong task you have performed. Additional task I ask you to prepare a PPT for FMEA and you have also added in between FTA and you may made the my job complicated, because these two are not the same thing.

So, perform task in the wrong sequence obviously, if you if you if you know that suppose you are doing a project. And it has different activities to be performed and those activities to be performed in sequence there is some precedence relationship, you if you do not follow the business relationship and then either you will not be able to do the work or even if you do the work that will not be useful.

So, in that sense there are many many other examples which can be quoted here, that the vague a component or an element of a system fails that is what is failure modes. Suppose, I if you see in PHA we have discussed the missile system ace missile system

and we have we have we have given you that the missile head. So, you have seen that the um missile head how it fails different different structural failure also we have discussed that is that is failure mode of that missile head.

Similarly, in case of pump pressure tank system there the that tank rupture can be a failure mode ok. Although it is a huge one it is not a simple one tank rupture causes lot of things that is also failure mode. So, there can be relation between failure mode and deviations, but usually we do not go for this kind of relation. We use in different context hazop and FMEA. In hazop more of process parameter there are deviation and in FMEA it is more of the hardware part every component or the part of the component how they are going to fail and that is what is what is basically discussed here.

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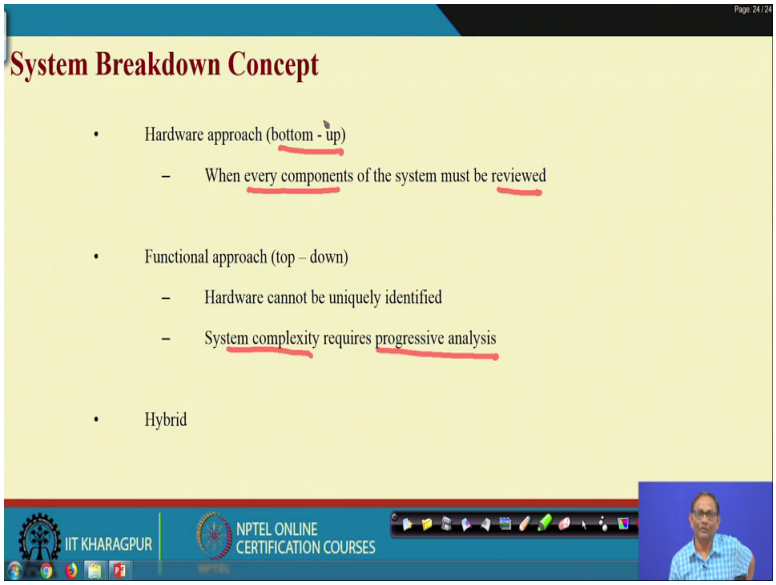

So, the if you want to do FMEA, you have to first breakdown the system up to component and part level that is very, very important because FMEA used usually at the component level. So, there are three kinds of approaches one is hardware approach bottom up approach, bottom up approach means a when every component of the system must be reviewed. Functional approach hardware cannot be uniquely identified may be the issue or system complex complexity requires progressive analysis.

What happen if we go for suppose in the pressure tank system. So, a component wise when you go you have you have you have already seen that component why the pressure tank, pressure gauge, relief valve, alarm, the pump, the timer, the counter, the switch, the

electric all those things, but you see pump is getting common from the circuit. So, there is some relationship. So, many a times what happen if we consider only one component then the dependent relationship with other component of the system may not be understood properly. And in that case you the your analysis may not be that strong enough from analysis point of view not from identification of failure modes point of view.

So, that is why it is written that system complexity requires progressive analysis ok. So, there may be situation when you require to go for functional breaking up. Now, the last one is that many times what happens sometimes you combine the two. So, that hardware approach and your functional approach or bottom up approach or top down approach and then you make a hybrid approach. Maybe you divide the system into subsystem for some subsystem go for hardware bottom up approach somewhere top down functional approach, because it necessitates to do to have better understanding about the failure modes in a system.

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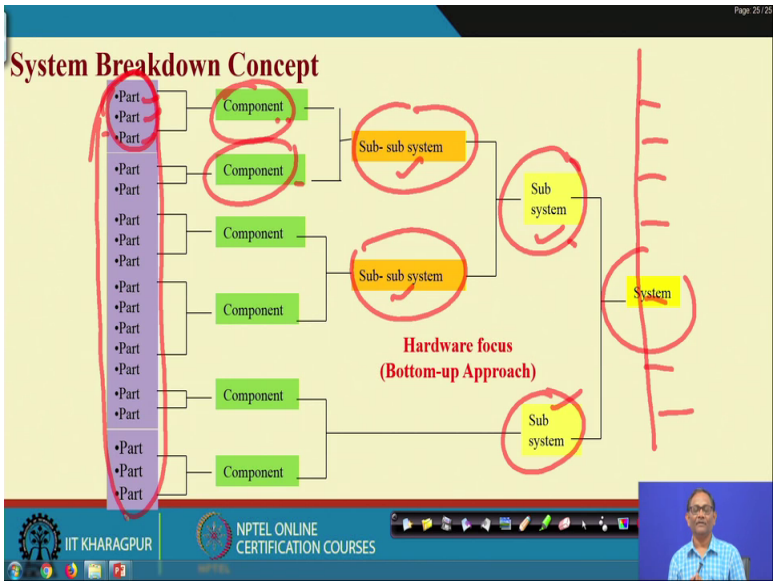

So this is what is our hardware approach, that is bottom up approach. You see what happen a system can have subsystem then can have sub subsystem then in this sub subsystems con different components and finally, parts. So, we are interested in failure modes here you consider part one part, two part, three like this every part.

And find out this part will fail how this part will fail how this part will fail then, these three part in combination will talks about failure mode of the component. Now for this subsystem this two component failure modes will be subsystem failure modes. And then ultimately this two subsystem failure mode will be sub subsystem failure mode will be this subsystem failure mode. And this side another failure modes will come from this side and finally, you will have a big list of list of failure modes of the system.

So, it may so happen that all the sail failure modes component level failure modes may not lead to the part level failure mode may not lead to component or may not lead to subsystem level failure mode. So, when we do compound hardware breakup, we basically are interested to know at the bottom level what are the failure modes in the detail a modes we want to identify; Now, the relation between that when the some of the failure modes finally, leads to the higher level failure that is a different issue.

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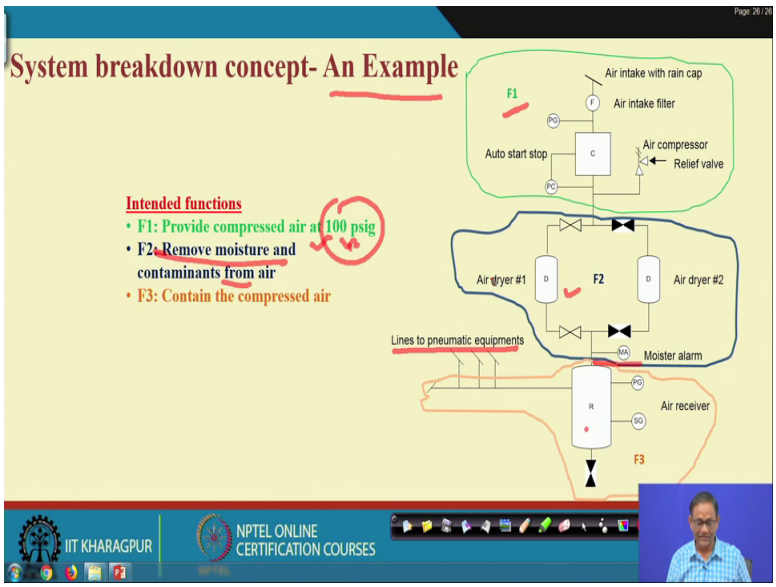

Then you see that: what is the approach with reference to that hardware approach an example. The example is here we are talking about an example is it is a compressor air system. What is actually here is the receiver actually I can say this similar to the pressure tank, that what happened it stores the compressed air and this compressed air is used by line of pneumatic equipment.

Now, this compressed air it is to be with a certain pressure range and it should be moisture free. And as a result there are two other function F 1 is provide compressed air

with the desired pressure level and F 2 it remove the moisture from this. So that means, the air what will be stored here it should be of 100 psig pressure as well as it is moisture free, because this equipment require the air with this pressure and moist free air. what if this is basically what is the total system, now I will show you the hardware approach of breaking it down.

This example we have taken from some sources and that is: what is say that could not locate this source. If anybody know please mail me in the discussion that already source then, so then next time I can add this.

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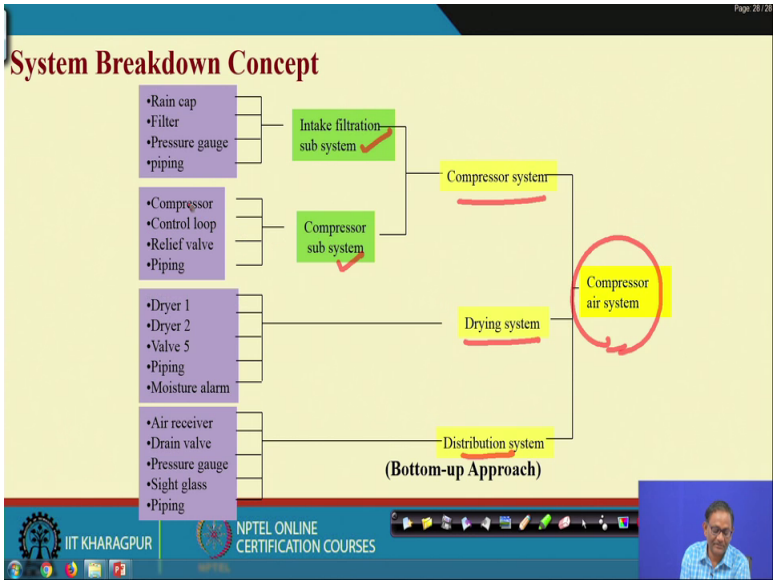

So, now what happen if I go by the hardware approach bottom up approach my totality is compressed air system. You see that compressor subsystem, drying subsystem, distribution subsystem, three things. Air coming to the compressor compress to required pressure then coming the dryer it is dried, then going to the distribution system in the receiver and going to the pneumatic, pnumatic machines

So, compressor system had intake filtration subsystem, compressor subsystem, drying system there is no further subsystem. Straight way the that component level and distribution system also component level. Now, intake filters and subsystem rain cap filter pressure gauge piping, compressor system like this compressor control loop relief valve piping and these things. So, you can see these things these things if we go suppose rain cap, filter, pressure gauge and piping you see this is the case.

So, rain cap, filter, pressure gauge and obviously, all those piping this is basically a that intake system, intake filtration subsystem. Now if you say compressor subsystem compressor control loop relief valve piping, you see compressor subsystem that is compressor, pressure control, relief valve, piping, relief valve and pipelines are there.

So, in that way in that way the breaking up has taken place. So, you are breaking down the total compressor subsystem into comfortable. Now you will be interested to know the failure modes of these many components. So, let us see that: what are those failure modes.

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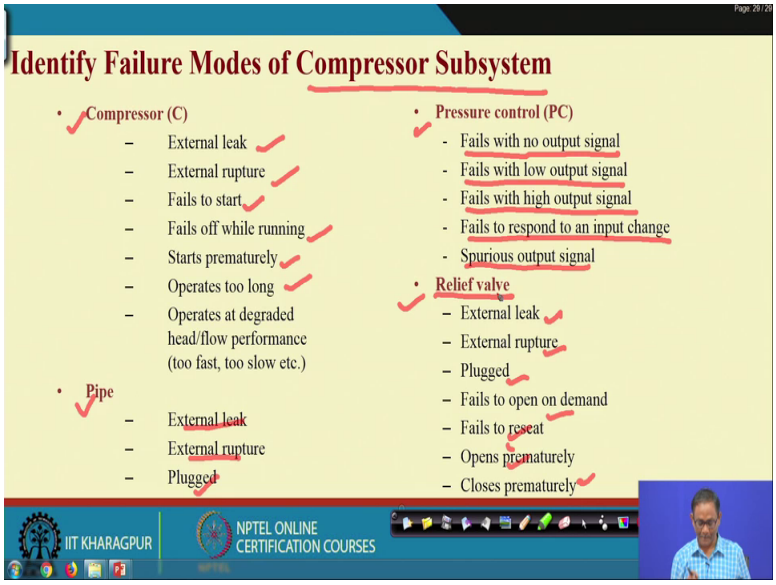

I am just showing you for one subsystem which is basically compressor subsystem. And you have already seen that in compressor subsystem what are the component one is compressor, pipe, pressure control, relief valve. Now, FMEA is also a team game, so your team will have design knowledge, system knowledge, hazard knowledge and obviously, experience that also counts. So, what happened you if you have design knowledge and a hazard knowledge all those knowledge.

Then what happened you will be able to find out that what is happening there what kind of failure modes that could happen there. One is the compressor case external leak, external rupture, fails to start fails off while running, start prematurely, operates too long, operates at degraded head and flow performance too fast and too slow.

So, similarly pressure pipe case external leak external rupture, plugged, pressure control, fails without with no output signal, fails with low output signal, fails with high output signal, fails to responds to an input change spurious output then external leak, external rupture, plugged, fails to open on demand fails to reset opens prematurely, close prematurely. So, all those things related to relief valve ok. So, this is this is very exhausti if you not its it is a very good list and this I have taken from that source and a its I have developed this long back. So, I will tell my scholar to find out the resource, but as I tried a lot, but I could not get it.

So, now what I mean to say here that once you have done the done the breakdown system breakdown structure. So, you have gone up to the component level for every component you find out the find out the failure modes. Then a list of failure modes will be identified once you have that list you can do the analy that failure mode an effect analysis ok. So, I will discuss this failure mode and effect analysis.

So, I hope that you got this may. Let me repeat the system breakdown structure that this one bottom up approach and top down approach this is bottom up approach then this is the example I have given you. And this is what is basically the with reference to the compressor system. And then we have seen that compressor particularly this one the compressor subsystem I consider and this four components their failure modes are identified ok.

So, similarly if you take any other system your own system you take and break into this manner. then what and finally, find out all the components and then see that what the failure modes, most of the time the failure modes will be available in open source ok. So, may be from reliability handbook also you can find out the failure modes, otherwise your team must be able to find out the failure modes ok.

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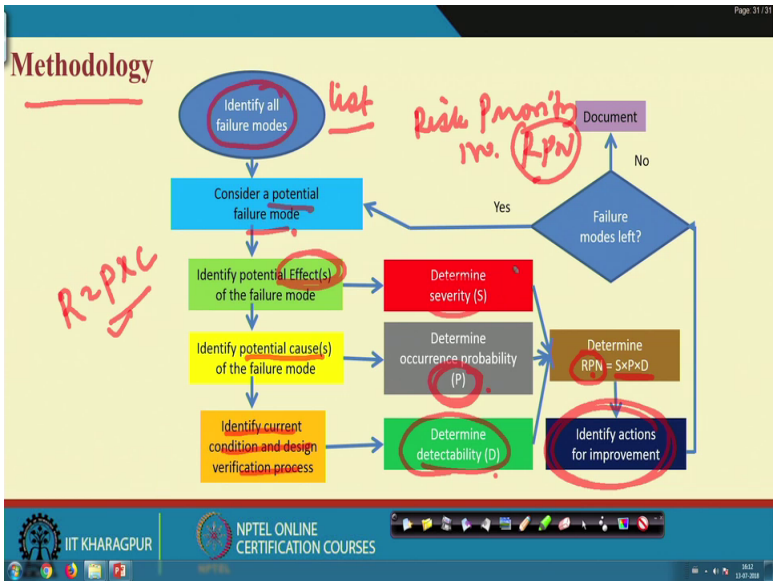

So, once you have failure modes then what is the state the methodology means doing failure mode and effect analysis. What is the methodology? Identify all failure modes, like if you are interested to develop the do go for failure mode and effect analysis of the compressor subsystem, then there are four components and for every component all failure modes are identified, so a list is available.

Now, consider a potential failure mode, maybe from your from your experience of the team will find that even though there are 50 such failure modes, may be may be 20 failure modes are potential modes other may be trivial. So, you consider a potential failure mode. Then three important things you have to do, one is if failure occurs in that mode. What is the effect, what is the consequence that is going to have. So, this will talk about severity for example, in the in this case in this particular case. So, if you if you if you see that external rupture. So, the compressor rupture what will happen will not create a huge thing. So, in that case severity will be high other cases severity will be low you getting me.

So; that means, for every failure mode, if that failure mode happens what are the effects that you identify, from those effects you will be able to for determine the severity level. We will discuss in the next class the different scales to find out the define severity probability and consequences ok. Then the second one that for the every failure mode you find out the causes why that failure mode happens. So, if the failure mode occurs

what will happen, that is the effect why that failure mode occurs that is the cause the cause will give you the probability, cause will give you the probability.

Effect will give you the severity; cause will give you the probability, but in addition another important one which is not considered in traditional risk analysis. When we say risk equal to P cross C probability and consequence means this two probability and severity, but the other one is important one is the detect ability. Failure modes happened a component failure happened, but is your system is able to identify that that failure mode has happened. So, this is very important and that is known as the detect ability of the system, there is an external leak there is leakage of gas let it be the valve will choke, but is it. So, that our your system is configuration is such that you are able to detect that that particular failure mode has occur.

So, that is possible identify the current condition and design verification process. So, if you if you if you do this what we will find out that you will understand what is the detect ability of your system towards the failure mode occurrence, so this lead to detect ability. So that means, then we are calculating then we are calculating risk, but not in this formula we are saying RPN means risk priority number priority number RPN.

So, instead of R we are writing RPN which is multiplication of this three that severity probability and detect ability, for every failure mode you find out this RPN. Now when we discuss the scale for detect ability, severity and probability you will find out that how this multiplication is done why this multiplication is done also ok. So, that part will be discussed later, but suppose you have given this given a scale of severity, probability and detect ability separately for a particular failure mode all three values are there then you will find out RPN for this failure mode. So, what happened all potential failure modes RPN will be identified?

And then what happen in between what you will do you will see that whether RPN value is significant or not means it is high or it is beyond certain value. So, that it is a potential when it should be considered, then what happened you basically talks about action point for improvement like in hazop what you have done you say once the causes consequences are known you are basically recommending something.

So, that these thing will not happen similarly for every potential failure modes you have to identify the actions for improvement. Whether the either improvement in terms of

probability of occurrence in terms of severity of the failure modes in terms of detect ability when the failure modes are occur. So, in either of though the three or in combination you tell what is the actions to be taken. And then what happen for every failure mode when you do you just say that whether any other failure mode let if yes take the next one and repeat this process if no document this.

So, what is the FMEA documentation that also we will discuss in the next class? So, this is what is basically the methodology or other way I can say that failure mode and effect analysis. I am not giving you any example of all calculations, but we will be discussing those things in the next class. And for the time being if we understand that failure mode and effect analysis is a very useful hazard identification analysis techniques technique and it is used almost everywhere, but it is more suited when we are talking about equipment or machinery related failure. It is comparable to other analysis like hazop and it is also a applied in other areas apart from safety, like in case of quality that six sigma and all other cases even in the business risk analysis also this failure mode and effect analysis is used.

You should not forget that it is a team game you must have the from safety engineering point of view must have the design knowledge you must have the hazard knowledge, you must have experience gathered with in terms of doing failure mode and effect analysis or in terms of the failure modes at what already has take have taken place. And then you require to calculate the severity; the probability and detect ability for all the failure modes. And then you must compute the RPN and through RPN only you will be able to prioritize the failure mode and for every failure mode potential failure mode the actions must be suggested. The actions can be in terms of reducing severity, reducing probability and improve improving detect ability.

Thank you very much.