Six Sigma
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Lecture No. # 38
Failure Modes and Effects Analysis (FMEA)

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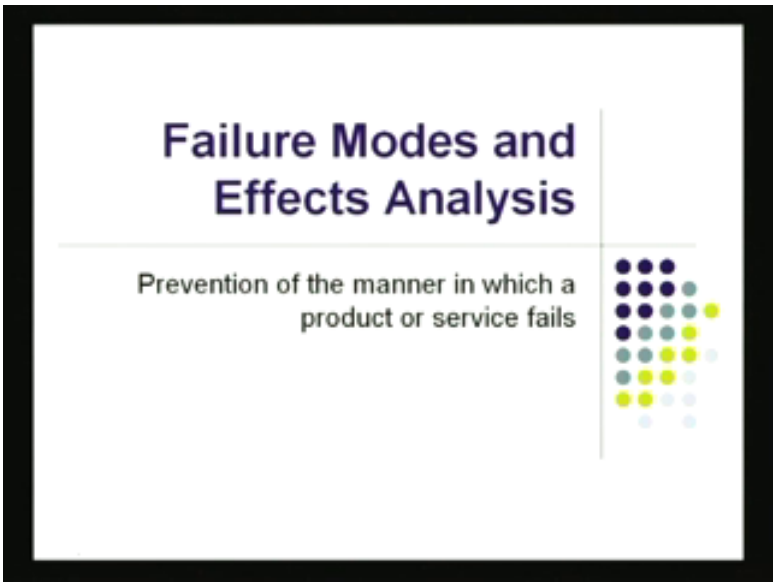

Good afternoon, we are beginning in and this time I am going to complete my two lectures, one lecture is just over; the second one is going to be on FMEA. And in this, we take a look at how we can predict the greater failure of certain products; these could be finished products or these could be for example a process. So, this is quite often utilized right at the design stage right at the design stage itself you'd like to do FMEA to try to make sure.

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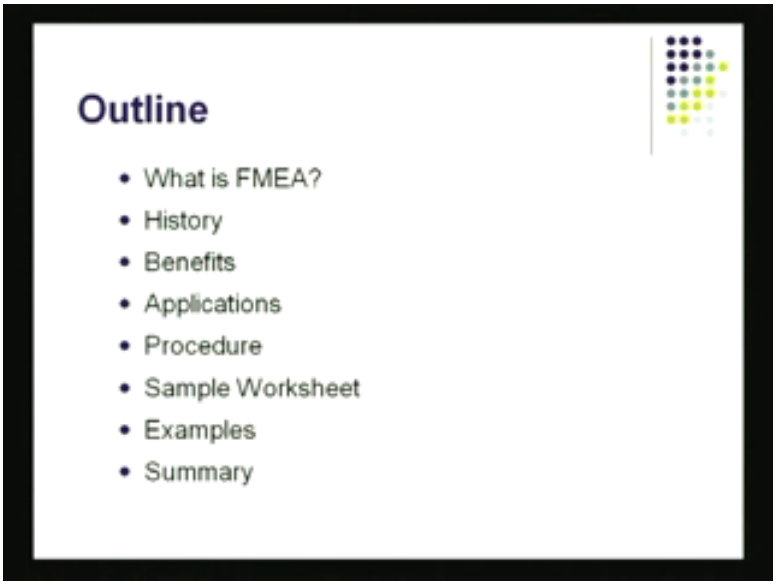

You can prevent, you can take all those preventive steps to look at the manner in which a product or service may fail. The outline of this hours talk is going to be; what is FMEA, little bit about the history of it, what are the benefits, what could be the applications of FMEA, this is something you would like to be able to see. The procedure for doing it, I'll take give you a glimpse of the work sheet which is there, and couple of examples and its summary. This is what my plan is for this session with you.

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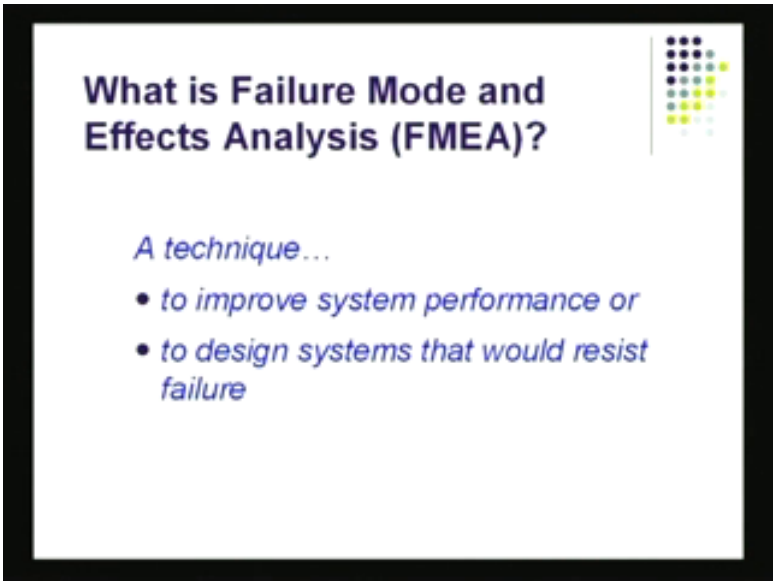

What exactly is FMEA? It is a technique to try to improve system performance, or to try to design systems that would resist failure; both of those are achieved by doing FMEA.

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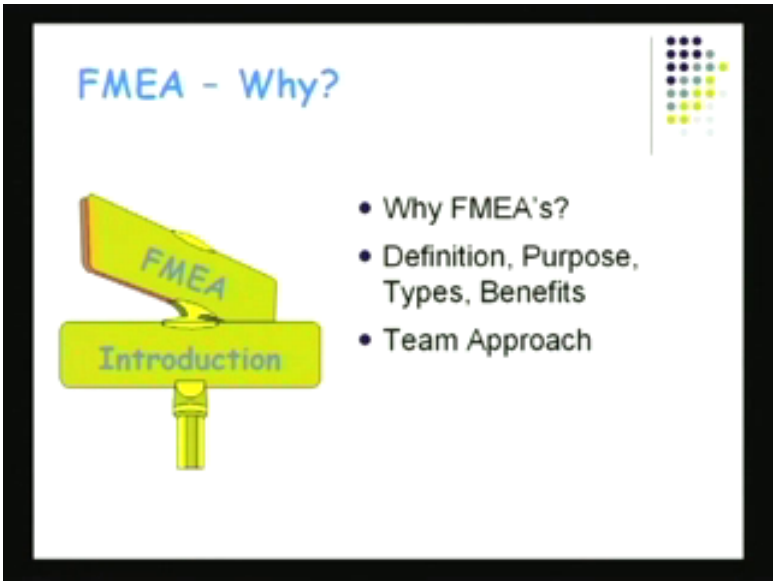

Why do you do FMEA? Well, first of all let us try to understand the definition and the purpose and the benefits and so on. I should just caution you that, FMEA is a team approach. In general, it cannot be done by just one person trying to work out the details of it.

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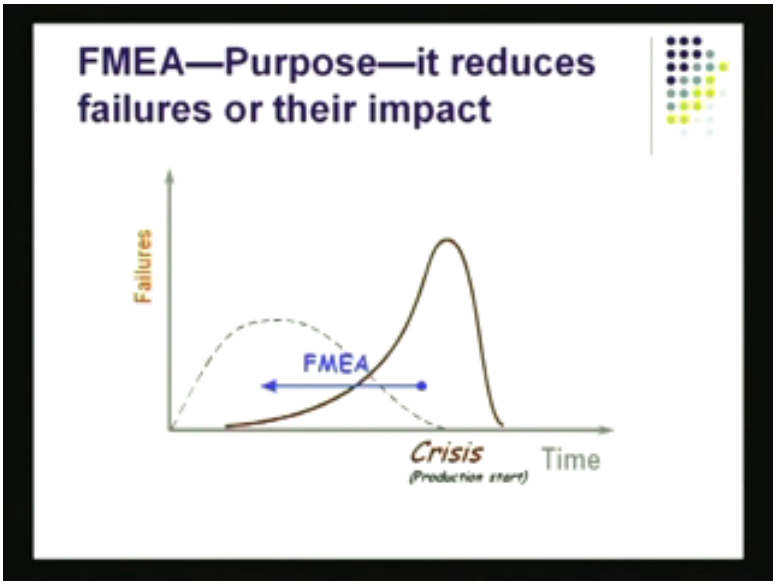

Something we got to remember is, the whole purpose for FMEA is try to reduce is basically to, try to reduce the impact of failures. And, in doing that what it really does is, prevents a lot of crisis. If you would not do FMEA then, the design or the process would be released as is without any kind of, you know kind of prediction of the chance that it might fail. It may fail to function as required or it may fail to deliver the functions; that is the performance that is that is kind of expected of with. That is something that could be there if you do not do FMEA. In f s o, FMEA is kind of a preventive predictive

technique. That is what it does, and it leads to actions; it leads to actions that will lead to improvement in performance.

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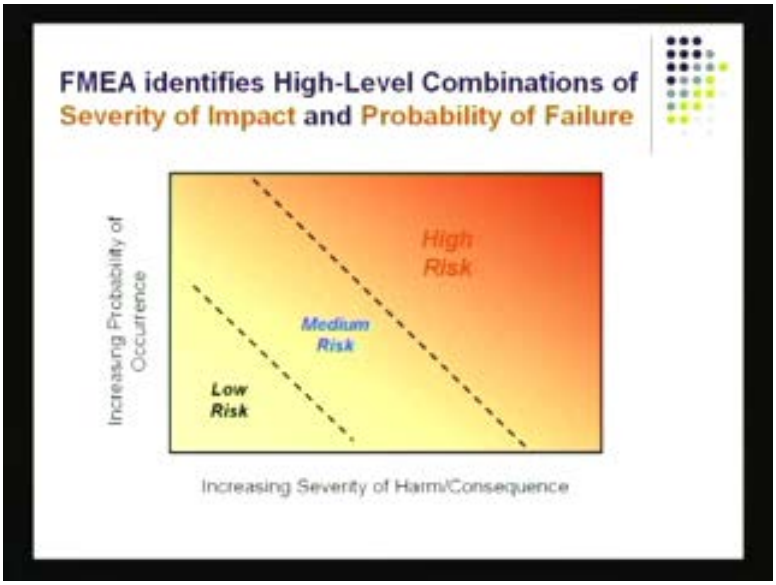

What exactly is the result? Well, there are two dimensions, whenever something breaks down or some failure takes place. There are, in generally speaking two or three things that happen. So, I am going to show you that slowly. The first thing of course is, there is the severity of the impact, that can be high or low depending on the nature of the feedback, nature of the failure that took place. You might get some feedbacks saying, that the impact was high or the impact was low. The other aspect is the probability of it; the probability of it occurring, that again can be high or low. So if you got a situation, when you got a high probability of failure and the impact is large, and that the consequence, the adverse consequences lead to things that you do not really want, then you got a hideous situation and that is, that red area there. If you look at the if you look at the picture, there is that red area and that actually shares says, if my product ends up there; if my process ends up in this area, I have got to make every effort to either reduce basically the likelihood. So, I should try to push it down this way, or I should try to take some preventive steps so I can reduce the impact. The whole idea is to shift a process, so the system which is here move to this side move to this side. As you go from here to here basically, you are trying to reduce the impact, also trying to reduce the likelihood. And this is achieved by doing FMEA; this exactly, this objective is achieved by doing FMEA.

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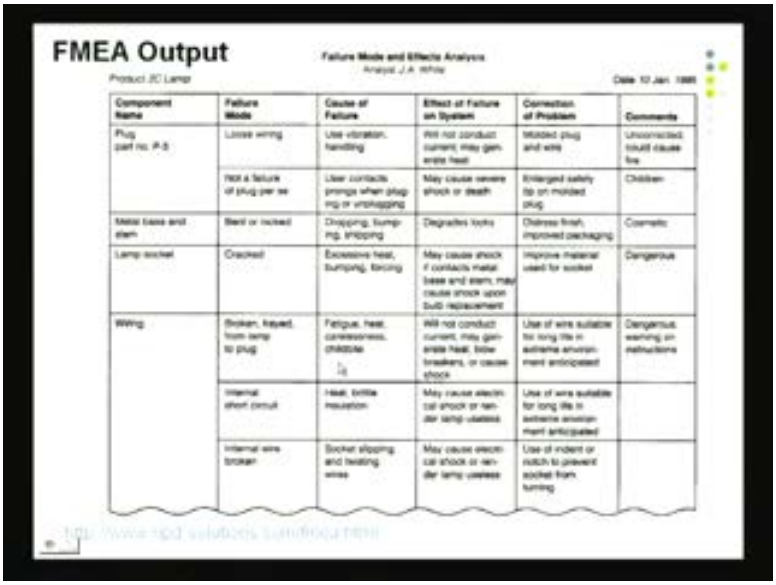

Let us take a look at the output; what exactly happens at the output? Now, if we look at the system for a few minutes, for a couple of minutes, you will find there are certain components in the system and that is gone through; this particular system is already gone through some kind of FMEA analysis. So the component names are given there, component that make up the system. Then failure modes, in what different ways could that component fail; for example, loose wiring or a failure of a plug or something like that itself. What is the causing of that failure? It could be vibration or something else that also is pin down there then the effect of that failure. Causes in the failure would lead to then again you have got something called the effect of the failure then the correction of the problem. What all things I can do to try to reduce either the impact or the likelihood of that thing, and then I put some general comments there and this is what I do with every component that makes up the system itself.

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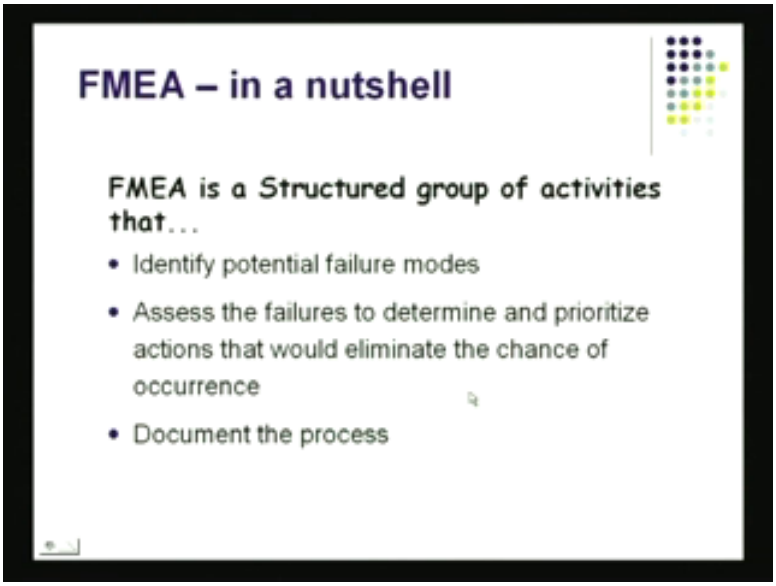

So this is going to be, this work sheet is going to be the output. At the end of your FMEA analysis, you will end up with the work sheet like this. And of course in addition, you will also end up with some priorities because, you could do many different things. And the FMEA approach the FMEA approach also tells you, it gives you a sorting of priorities; it tells you what are the things that you must take some steps to try to prevent now; try to take some corrective action now. What are the other things that will probably that could probably wait, and you will probably take some time to figure those things out and probably take some corrective action but, the ones that have high likelihood of failure and also have a high impact, those actually are the ones that should be addressed as quickly as you can. When you do that, you are really following a structured approach. You will identify the potential of failure modes; you will basically identify what different ways could this system fail; you will assess the failures to determine the prioritizing actions. And, this is something that we got to be able to do because, you must attack the more important ones first.

Then of course, once you have gone through the analysis, you got to document the process; you got to make sure you release the action items to those people who are supposed to be able to act on this.

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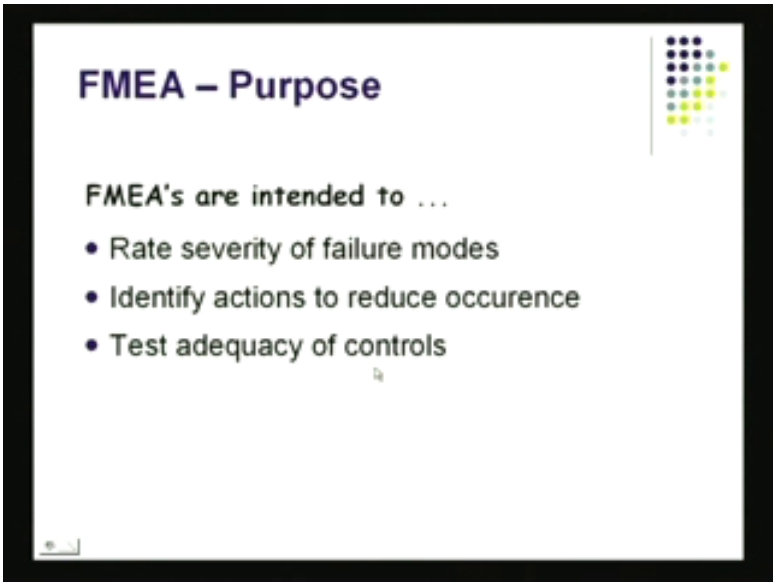

FMEA is intended to basically rate this severity of failure modes. Failure modes are those different ways by which a product could fail, or a service could fail. Identify actions to reduce the occurrence basically to impact the likelihood itself. And of course, test the adequacy of controls, you might have some control actions put in place. You would like to probably check them out. In that, the control actions themselves do not fail this is something you would like to be able to do.

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Some history of FMEA, it was created by the aerospace industries in the nineteen sixties to try to make sure that, there were no not as many failures. And flight is something that can cost you, that can lead to a loss of life. That is something very very costly and you would like to avoid as much as you can. And of course, the loss of the equipment that also is something you would like to minimize.

Ford began using this in the automotive area to try to reduce break down of some cars, and its vipers adapted by the big three when they moved slowly towards QS 9000, they started using FMEA. The big three's are the g m, the Chrysler and Ford. These are the big three automakers, they started using FMEA. And the automotive action group, industry action group; this is a group that basically formalizes lot of action which are going to be there to benefit the companies to benefit these three auto companies there.

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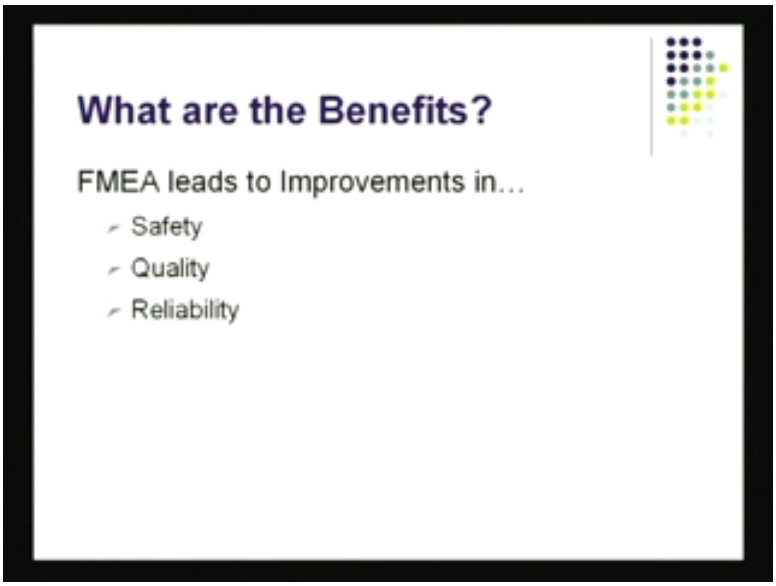

So what does, what are the benefits in FMEA? Safety is something that you get out of this. You improve quality and also you improve liability; all those three things you basically impact.

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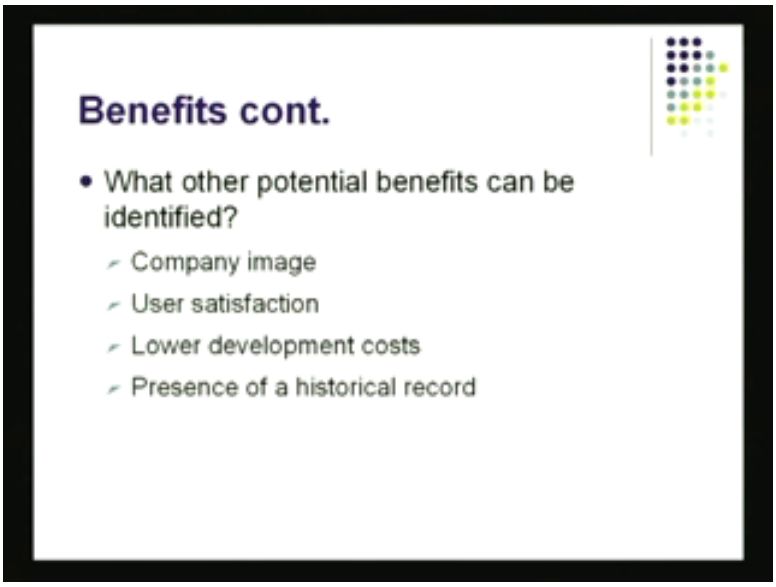

If we continue with the benefits, the potential benefits can be potential; now those are those are the previous ones with the real benefits. Now, there are some potential benefits, the company image may improve users satisfaction, is also something that might also improve low development cost because, if you have already done FMEA, it probably puts you under at a higher grounds sort of. And also the presence of a historical record, this is also something that is like a benefit.

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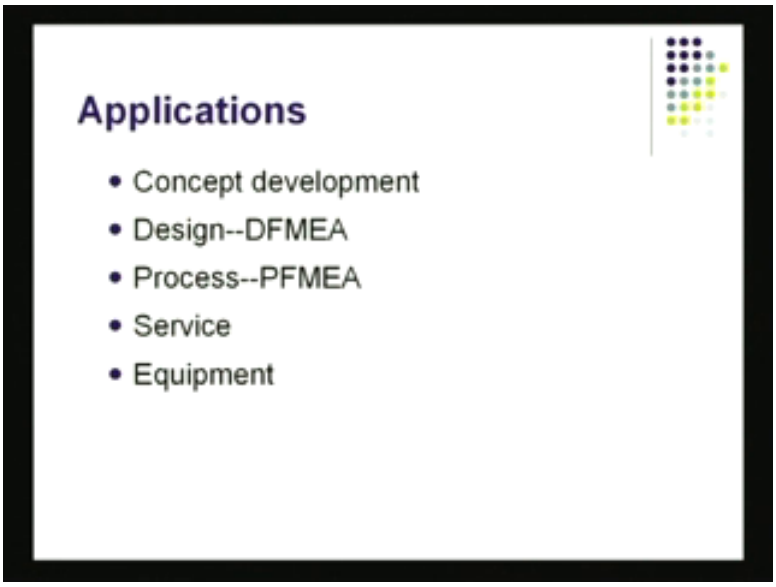

We will find out how did I reach certain decision; decisions during design or in the development stage. What all things did I go through to try to do this, that comes very handy when you are trying to do the same job again, you got a history there.

And the applications where you can apply FMEA is concept development, when you just basically trying to conceive a new product that is like one place you could probably use FMEA. Design FMEA this is called DFMEA; this is DFMEA this is one place where FMEA can be very very effective because, you are really trying to prevent before the new product comes along; before the new design is converted into a manufacturing product, you are trying to predict as much as you can about the likelihood of its failure. This is something you would like to be able to do as much as possible. And of course, process FMEA so many processes they break down in process and you would like to be able to see, can I reduce the likelihood of that failure or its impact; this is something you would like to be able to do. Now, more and more services are becoming a very significant aspect of our economy worldwide globally and services can also fail because of variety of different reasons. So, we are also getting into now doing FMEA for services and of course equipment, FMEA is done for there also.

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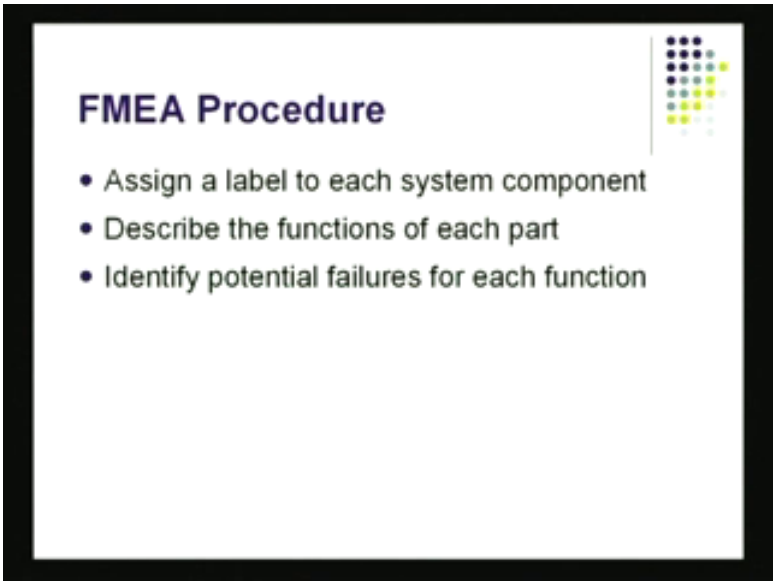

If you are trying to do, if you are looking for a procedure, you got to start with the component level. And you would like to see, what are the functions of each of these parts and sort of try to come up with some sort of way up basis to say that the product or the component may fail in this manner. This is something you should be able to do.

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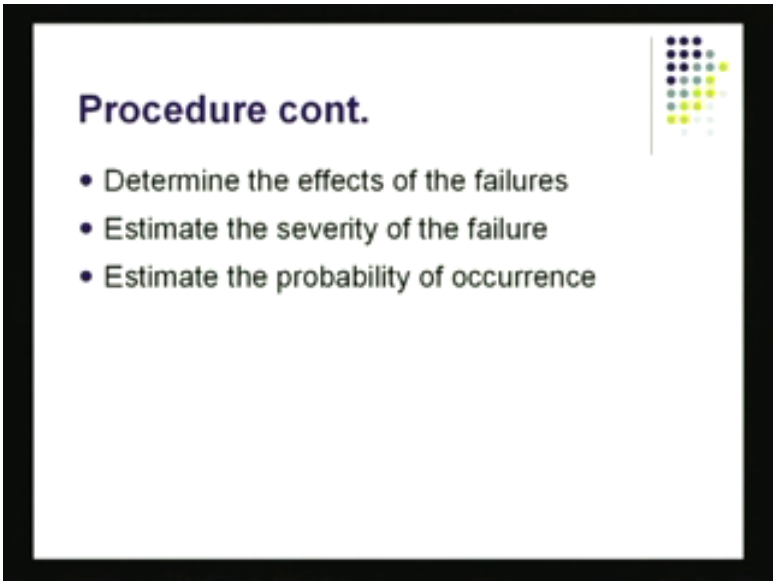

If you continue with the procedures, you determine the effects of those failures there, this is something you would like to be able to figure out. And then of course the severity, what is the impact? And what is the likelihood? Both of these things, we got to figure out. As much as possible, whatever it is you are trying to improve, it could be for example, the cover of this it could be the cover of this CD, this could fail in certain ways; it may actually damage the disc. The disc is inside and if this design is not right, it may actually end up damaging the disc, or it may just come off the locks; it may come off the hinge; for example, or it may crack, or it may scratch the disc and so on and so forth. So many different ways this cover itself could really lead to a failure, a failure of the total system.

So, you would like to basically understand, the different ways it could fail that will be the mode, then you would like to make sure what is the likelihood for this happening and then what is going to be the impact, and then will I be able to detect with that, you will probably work at various components; for example, you might look at the hinge; you might look at the cover; you might look at the plain surface there, the finish of it and so on and so forth. That little paper that is there for example, some paper is there, can that come off; can that actually do interact with the disc in any manner at all. When the disc is put in place, it should not the surface suddenly should not probably touch the bottom of the thing. So, in fact there should be some design modification right there, you may not be able to see it but, there should be some projection there that holds the disc. It is a very delicate thing; it should be held there in the right place, in the right place and it should be portable also. I should be able to carry this in my suitcase; for example, or in my briefcase or sometimes; I put in stick it right with my laptop and I carry it across town and so on and so forth. So, that is also something that this guy should be able to prevent. My loss is going to be loss of data, loss of that disc itself. That is going to be my impact and what is the likelihood; this is something we got to figure out. And if there are actions required, then of course we will modify the hinge, or modify the stand or modify moulding or do something there to try to do this. This is something we should be able to do. When you do it all; eventually, you will got you got these numbers there you got the likelihood and you got the impact, these should be quantified.

Then you got something called detection probability. You should be able to detect that there is a problem there, that also is part and parcel of doing FMEA. You multiply these three quantities which is the probability, the impact quantified and the detection capability; if you multiply these three, you will end up with something that is called the risk priority number. You end up with something that is like, if its if delectability is low obviously its more serious; so you would like to give it a rating that is high because, it got poor delectability.

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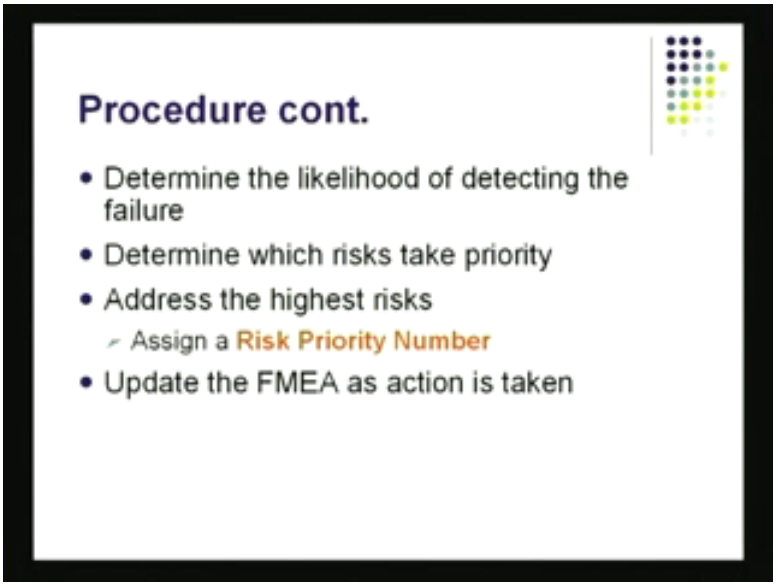

These are things when they are multiplied together, you end up with something called the RPN, the risk priority number. And risk priority number basically helps you to try to prioritize the different actions which are which this particular design deserved; for example, you would have RPN for the hinge; you will have RPN for the surface; you will have RPN for various things, and then that is what give that, what give you a hint as to what how, what should be the priority in which I should be able to do it.

You could even do a FMEA for your glass; for example, various ways you could damage this glass; never mind breaking it but, when you just lay it on a surface for example, could it could the glass get scratched; could that impair my vision for example; could it collect dust and so on and so forth. So, those are some of the things you would like to be able to predict as much as you can right at the design stage itself.

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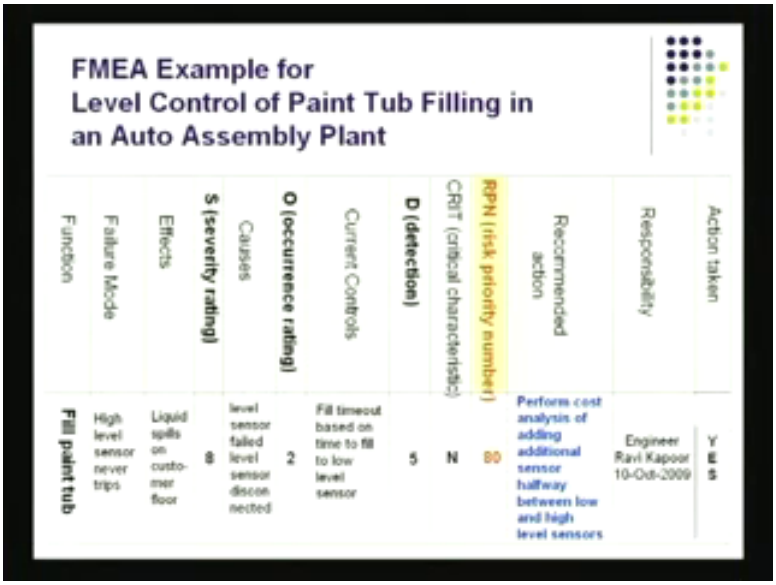

So, there is almost nothing that should escape your FMEA. You end up with something that I call the that, we call the work sheet. Here is an example; there is an automotive company and that has got an auto assembly plant, and it is got a paint shop; that has got a tank and this tank holds different types of paints, which are required to paint the vehicle. The surface of the vehicle for example, and there is a some sort of automatic system that fills up the tank, the paint tank then it clicks and then the automatic spraying starts and so on and so forth; that thing goes on.

Now, one could actually ask in what different ways could the function the impaired. So, if you look at the worksheet now, the function is fill the paint tub, nothing more and nothing less, just fill the tub. Failure mode is that the high level sensors, never trips even if the trip got the tank got full, the high level sensor did not trip. What is the effect of it? That the result of this failure, liquid spills on customer floor for example the user; in this case this paint painting machine that is supplied by somebody else. The car manufacturer does not produce this paint painting system so, it has been produced by somebody and it is been mounted there, it is been installed there. So, the automotive auto manufacturer is relay customer, if paint spills over it will fall on the customer's floor so, that is like a consequence, that is like an effect.

What is the severity? And this severity is rated on a scale that is like between 0 or 1 and 10. 10 is of course, high very severe. In this case, the engineer he is sort of failed looking in the looking at the damage and the clean up required and so on and so forth. He gave it a rating of 8. He say, if there are frequent failures like this, that would really end up probably shutting down the production line. What are the causes? What could have caused this? Now, I am getting into that fishbone diagram. You might remember, we had a we had a little diagram called the fishbone diagram. While we had the effect at the end and we had various causes leading up to that. That fishbone diagram is a brainstorming tool by which, you basically people who are working in that area they would know very well, what all different things could contribute to this failure there. So, that is something that I will be doing there and I would be tracing down to the causes.

And, the occurrence rating and this is something that of course, is the likelihood. How likely it is to be, and they have given it a low rating. That means, it is not very likely to fill there. The current controls current control is based on the you know the fill to the low level sensor, there is a low level sensor there. The moment that low level sensor you know, its indicates that the tank is empty and the this paint tub is empty, it starts pouring liquid; it starts pouring. it should stop the moment level gets to the right level there. What is the chance of detecting that the level has been the tub has become full, that detection probability they have given it in number of 4. Their capabilities have rated it 5. And of course how critical is it? Is it critical or is it non critical? Now, critical is something that can lead to a loss of life or loss of property. Hopefully, those things are not happening, just some mess on the floor so that can be probably cleaned up, not big deal there. So, its being regarded as something that is non critical. If it is critical, action has to be there now. Then of course, you multiply 8 which is severity times the likelihood; which is like 2; which is 16 multiplied by detection capability which is 5, you end up with a number that is 80. 8 0 is the RPN for this particular item there.

Now, this RPN is the number that will indicate how important it is for me to fix this problem there. this potential problem there It is going to be, now this 80 is to be compared to other things that might have probably picked up an RPN of 20, 30, 40 or may be 200. We do not really know what all different things can go wrong in this plant. So, that is something we got to figure out but, before that of course, we got to do the RPN for every kind of function that can stop because of various types of failure there. Then, what are the recommended actions? Recommended actions are perform the cost analysis of adding another sensor half way perhaps between the low and high level sensors. That is like a recommendation because, that is going to reduce the likelihood and who is going to be responsible for it, there is an engineer Mr. Ravi Kapoor and he was told that as of 10th of October 2009, kindly get this fixed and then this got filed; this worksheet got filed and the report we have back is the action was taken, and the problem has been fixed and they have taken this corrective action, which is like they have installed a level sensor that is half way between the full and the empty positions.

So, this is our work sheet; this work sheet basically helps you identify what could go wrong; find out its impact; find out its likelihood; find out its detection capability; and then workout something called the RPN, which is going to give you a relative importance, relative significance of fixing this problem as posed to others. And then of course, the preventive action or the corrective action and then, assigning this the responsibility for taking the corrective action to someone and reporting back on saying. So, just see how we have prevented a potential problem; and this generally, these turn out to be a high return projects, their ROI’s are pretty good.

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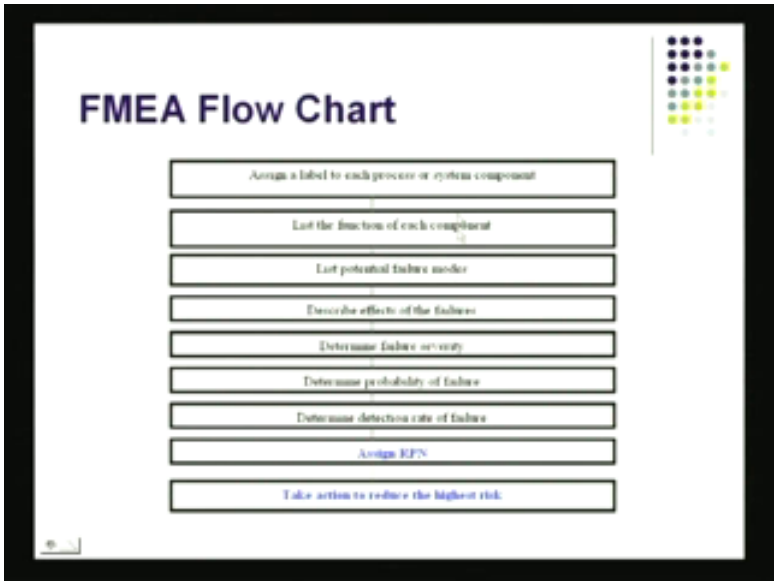

And, this is just a basically a flow chart about we went through. Assign a level to each process and system component which we did, that was the paint job, paint tub. There is the function of each component we also did that, it is supposed to fill up the thing, list potential failure mode we did that; differ describe the effects of the failure itself we did that; we have described the failure severity the other also we did; spill on the floor and so forth determined the probability of failure we did that; and the detection rate is also is something that we did. Then, we ended up with the RPN and then of course, we took actions to reduce the highest risk that is something that we did.

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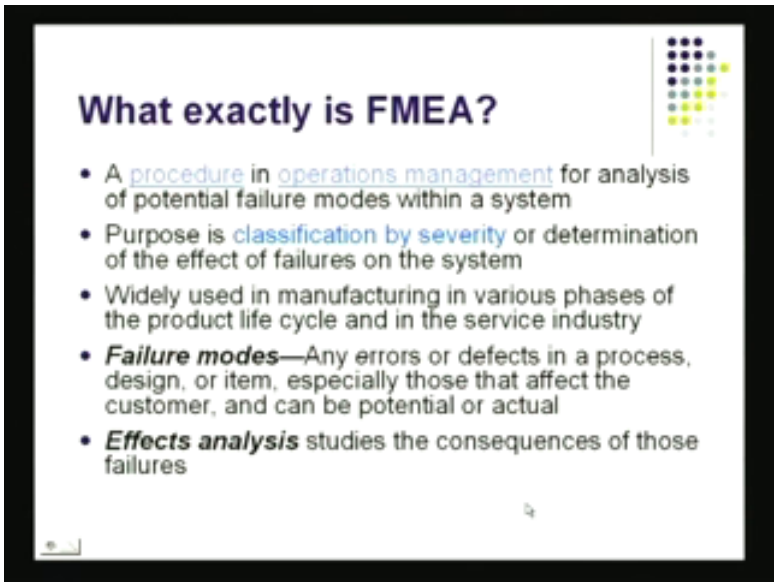

What exactly is FMEA? If you get into the nuts and bolts of this a little bit, there are two key things that you must go after. One is the failure mode, any errors and defects in a process design or item specially those that effect the customer can be potential or actual failure mode. These are the different ways the functionality can be harmed in some way

or it can it can break down. And, the effect analysis is the consequence; effect analysis is basically the consequence of something has broken down what has been the impact of it. These two things you got to keep in mind; how is it evolved if you go back to 1940s for example, that is when the army started first using this; the US army started using FMEA, a sub variation of FMEA.

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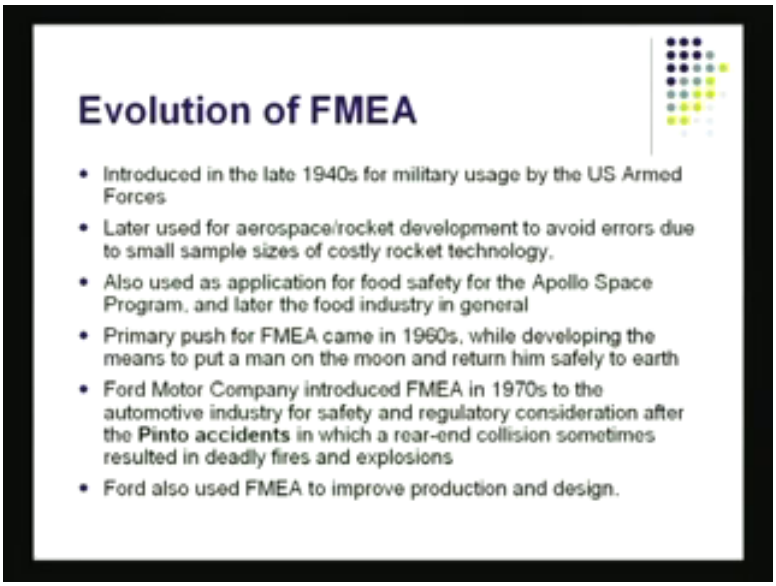

Then of course, from that point on if you take a look at today. There was a serious application of FMEA, which was introduced by the Ford company in the 1970s. They had a large number of accidents with their pinto cars and these let to loss of life and loss of property and there they did FMEA, and they located certain aspects of the design that had not been properly addressed, when the design was commercialized. So, this is like something that the results or the action items emerged out of FMEA during FMEA.

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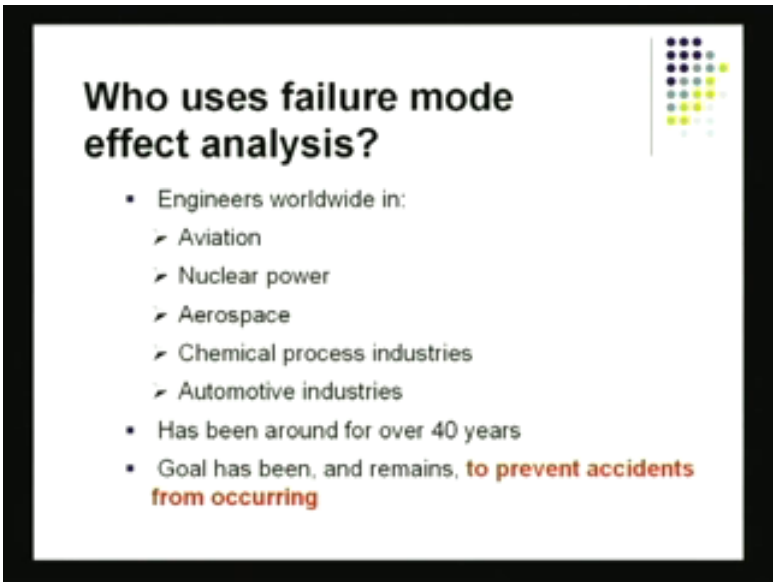

FMEA is also used to try to improve production. You have ongoing production going, you have an existing design that also can be done. Who are the different people who use this? All kinds of people; aviation people, nuclear power people, aerospace people, chemical industries, automotive industries; they have been doing it for a long time. And, the goal really is to try to prevent accidents from occurring that is really the goal.

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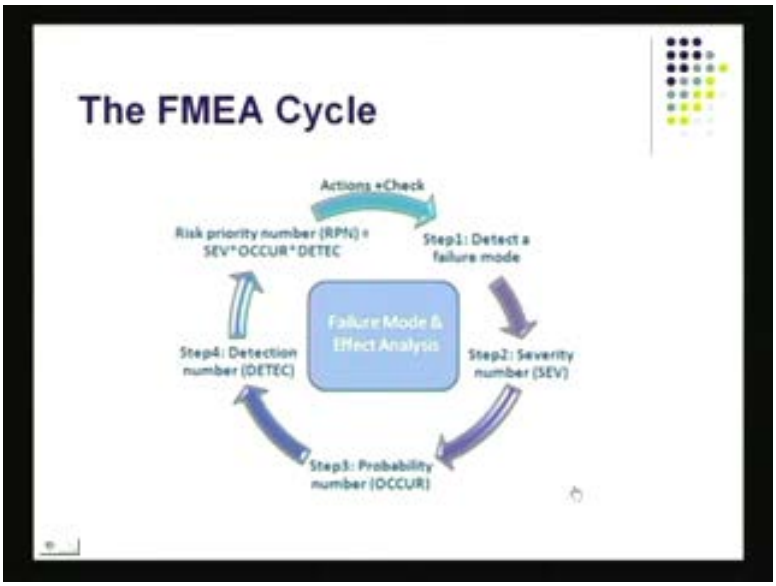

There is an FMEA cycle and if you look at step one, it is detect a failure mode defect try to find out what different ways can a product or a or a component or a service break down. So detect the failure mode and look at the severity look at the severity, look at the look at the severity of it, which is like what could be the impact from that, you would get to know the severity of it; what is the likelihood of it; and what is the detection number. We saw all of these things, when we worked at the work sheet, then you work out something called the RPN. Once you have the RPN, it can help you prioritize the the actions, the corrective actions as supposed to working on something else and getting your rib, getting your system improved.

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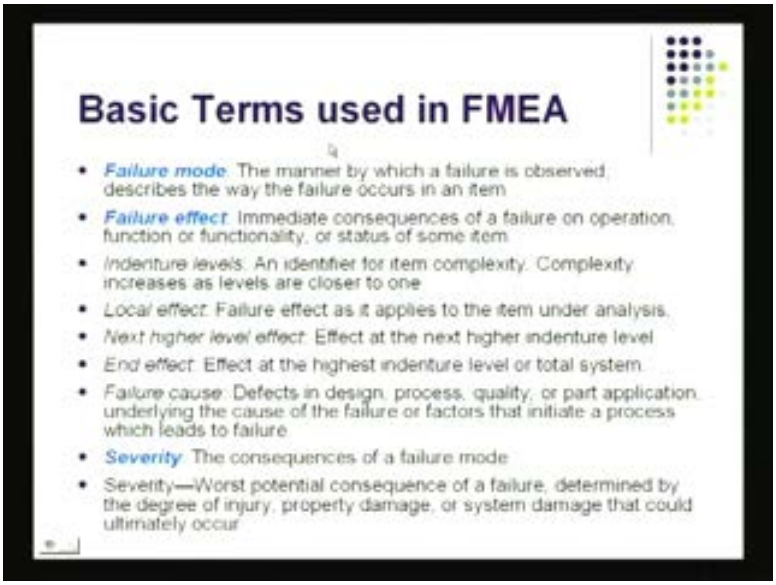

There are certain terms which are used in FMEA. There is something called FMEA, it is the manner in which the failure is observed and the effect of the failure is basically the consequence of the failure itself that is there. Then, there are other things for example, they could be local effect, end effect and so on and so forth. But, there is the important one which is the severity. It is the consequence of that failure. Basically, it is the worst potential consequence among failure. And, that is determined by the degree of injury, property damage or system damage that could ultimately occur; that is like something that tells you, how serious could this matter be.

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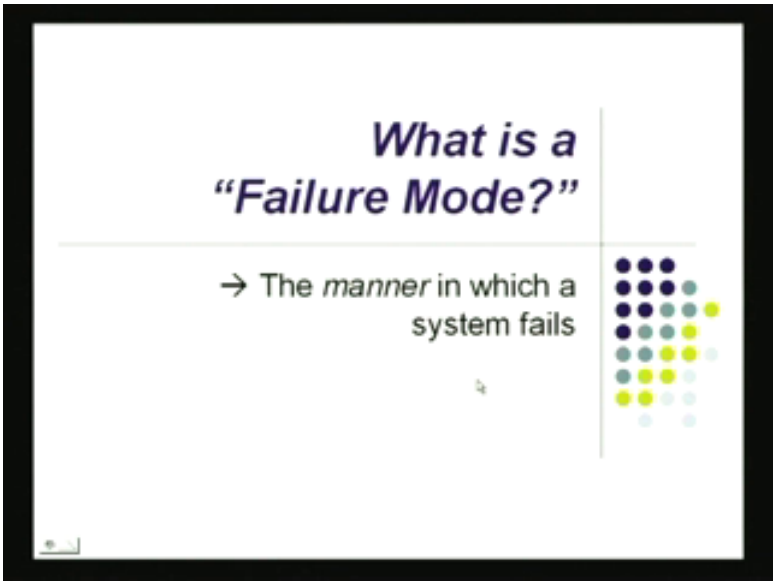

And, let us try to see the manner in which a system fails. What exactly is something called the failure mode.

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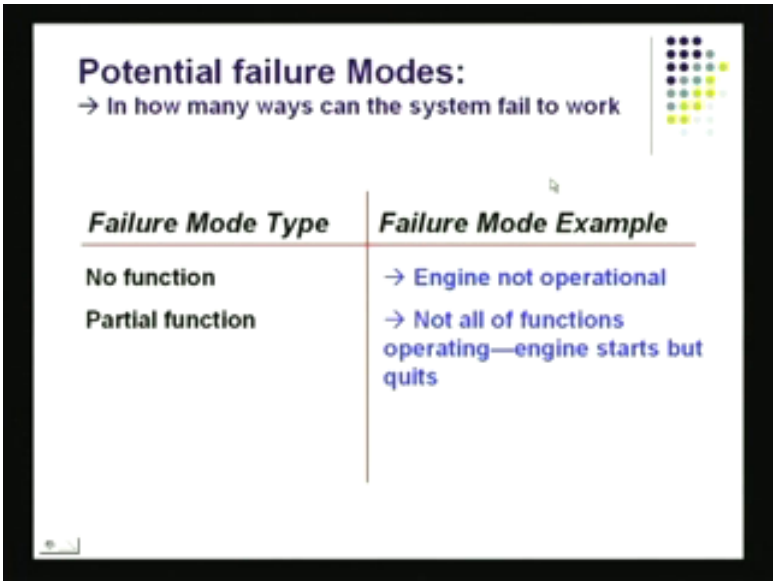

Let us take a look at an example. In how many ways can a particular, let us say a vehicle can stop functioning. Engine is not working and partial function is something that could be that is a mode of failure engine is not working, or not all function of the engine, the engine starts but it quits so that means, not all functions are properly working. So these could be the modes, these could be the different manners, different ways by which a by which a vehicle could would have difficulty in starting getting going.

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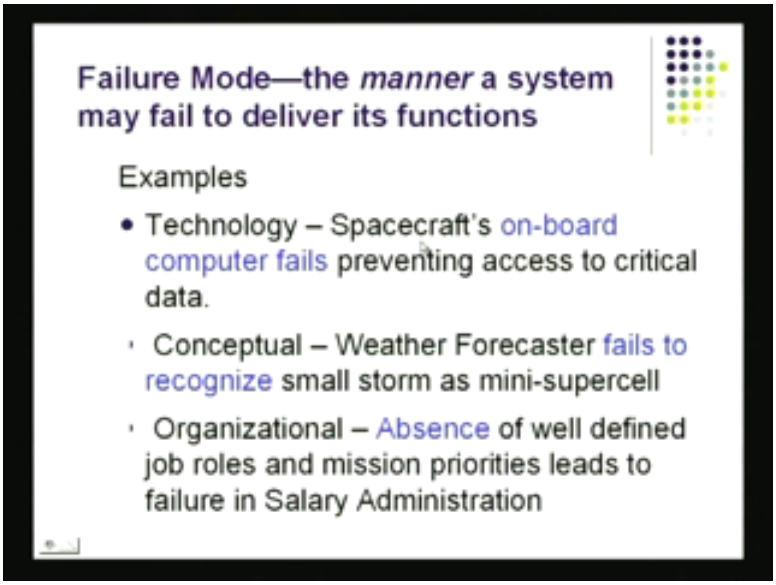

If you look at other examples; if you look at other examples for example, they could be a technology mode; the failure could take place because of technology for example. If there is a space craft flying and the on board computer fails for some reason; that is a critical failure. There could be conceptual failure and this can happen sometimes when person a person does not fully understand how to carry out his task, and this happens a lot. This could happen for example, I will give you couple of examples; one is you know

the people who are at the flight deck; they are the flight controllers for example, at the airport so you know there are certain training that they have to go through. The other kind of people who also have to go through these kind of training is people who do weather forecasting. They forecast these different, they look at pictures and from that they with their training they can figure out there is going to be a massive storm or snow storm or tornado or something like that. That is something, they are trained to do. There could be conceptual breakdown there because, the person's training is not complete or some aspect of it was not covered very well so he there is was a conceptual breakdown there.

Then of course, there could be organizational failures also; for example, you may not have the, you may not have well defined job roles and the result is that, also people probably do not understand mission priorities and there the result is this. There is failure in salary administration, because you penalize someone because he has not done some job. The problem is probably his job, the responsibilities in the roles they were not defined very well. Whose failure is this? It is not the person's failure; it is actually the organizational failure that led to this kind of consequence. This is something we got to be able to do, got to be able to fix.

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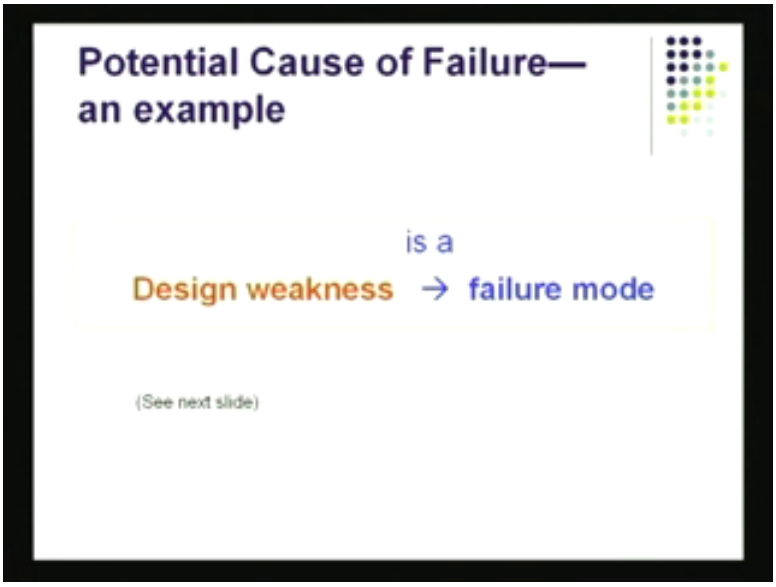

If there is a weakness in design, if there is a weakness of the design itself, if the design of the cover is not good enough, I will probably have a problem there.

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I am showing you an example here, which is like a designed effect. Look at the two parts of it; these are these are these are parts that are supposed to fit together. Now, this is a polar connection. Polar means, there is a positive end and it must go into the positive hole; there is a negative end that must go into negative plug that must go into a negative hole there. If they are of equal size you know and I know that, there is every chance that someone is going to connect it backward, connect the plus to the minus and a minus to the plus if the design is like this.

So, that can lead to a massive failure; that can lead to a disastrous failure, tripping and everything else and fire perhaps and so on and so forth, change that to this system.

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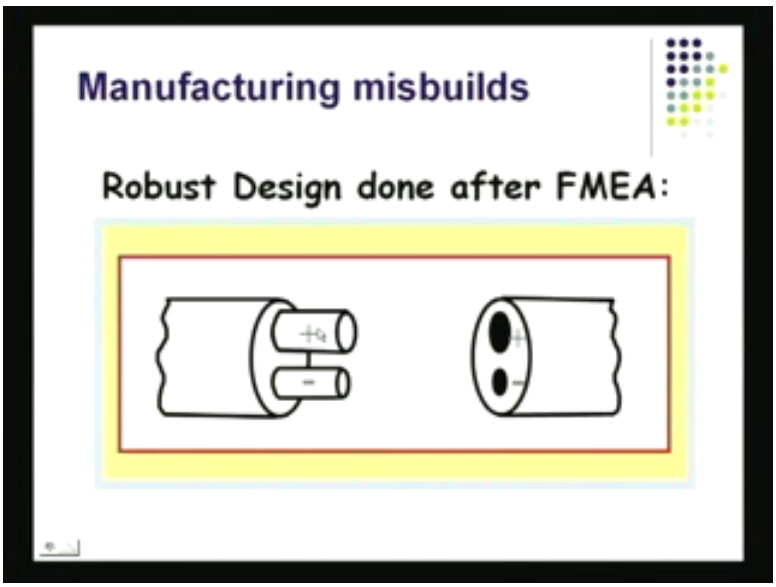

Look at this now, the plus has got a bigger plug and it has got a bigger hole there and the minus has got a narrower plug and a narrower hole there cannot be a misfit there. There just cannot be a misfit by doing, the plus is not going to go in there and the minus is not going to be easy for it to be pushed in, this cannot go in there. So, this is something as could be a prevent a misconnection, a wrong connection. This is like, we look at a modification, we had this design to start with and we changed that to this design which is a modified design. And this actually, is a way by which I am converting an old design to a new design and it will turn out to be good design in the end.

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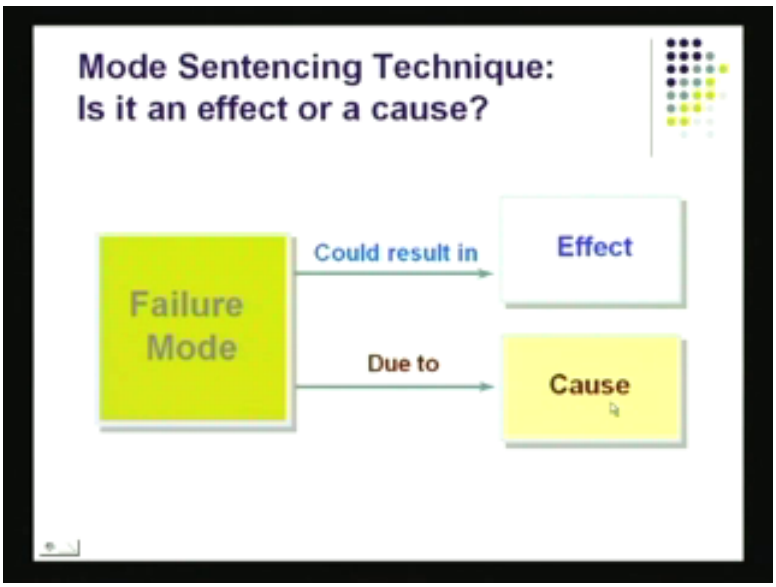

Failure mode, it could result in what we call an effect and it is due to what we call a cause. These are the couple of things we got to remember. We got to remember that with

every failure mode we have an effect and also we have a cause. It is the effect is something that actually results from it. But, the causes are the ones that cause the failure to occur. So we got to identify these things; we got to understand these things.

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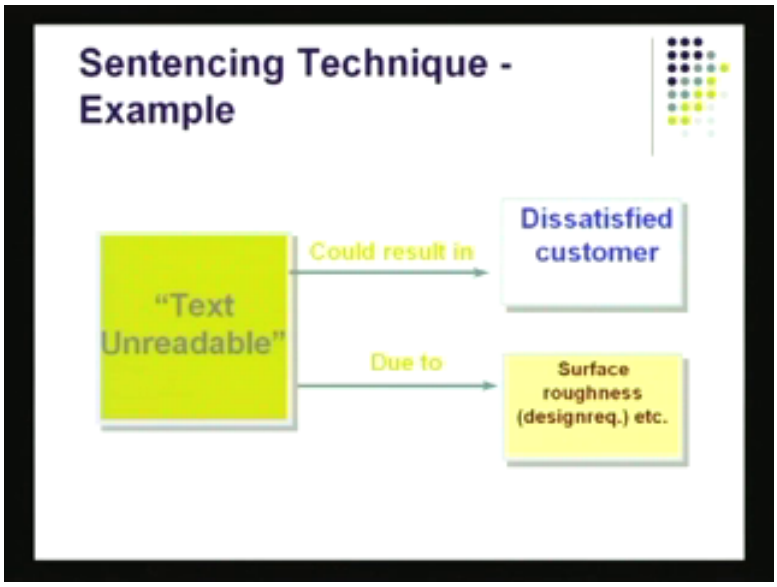

Take a look at another example; a text a piece of text is unreadable and that leads to the customer not being satisfied and this could be because of a variety of different things. Perhaps, the writings surface was known was not smooth. Perhaps, other problems were there and so on and so forth. That is why the text was not readable. So, there is the effect which is here dissatisfied customer but, it was caused by this surface roughness.

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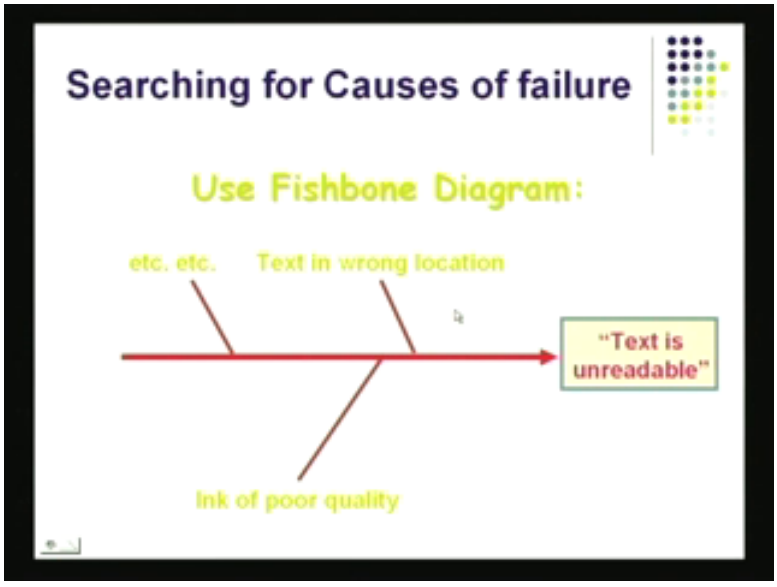

So, there is the effect and there is the cause of it, it is due to this. And many times of course, you would be able to fish this out; you will be able to basically figure out; what caused; what if you construct the fishbone diagram and you do something in a very disciplined way that is called brainstorming. The only thing you would do there in

brainstorming is, you do not control the number or the different dimension of the ideas that come up, that are given by people. This is something you do not try to control or do quality check out. Let it pour out and then hopefully, some gems will also emerge as a result of brainstorming.

So, the fishbone diagram is a great tool to try to do brainstorming and bigger basically figure out, many different ways by which this failure would have taken place, could have taken place.

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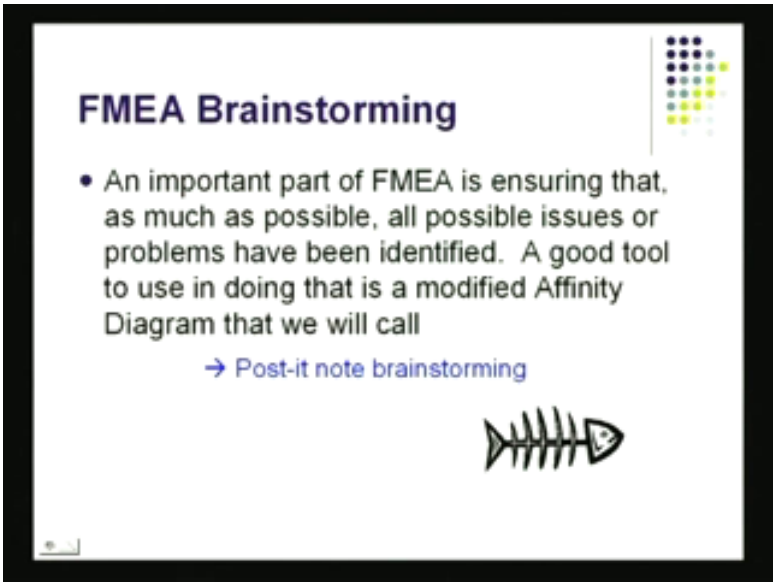

So FMEA can lead to brainstorming, this is something you would like to be able to figure out. And some procedure is given here, you can follow this, so you can follow any other one. My favourite is to start with the fishbone diagram and to try to populate the diagram by asking people many different questions.

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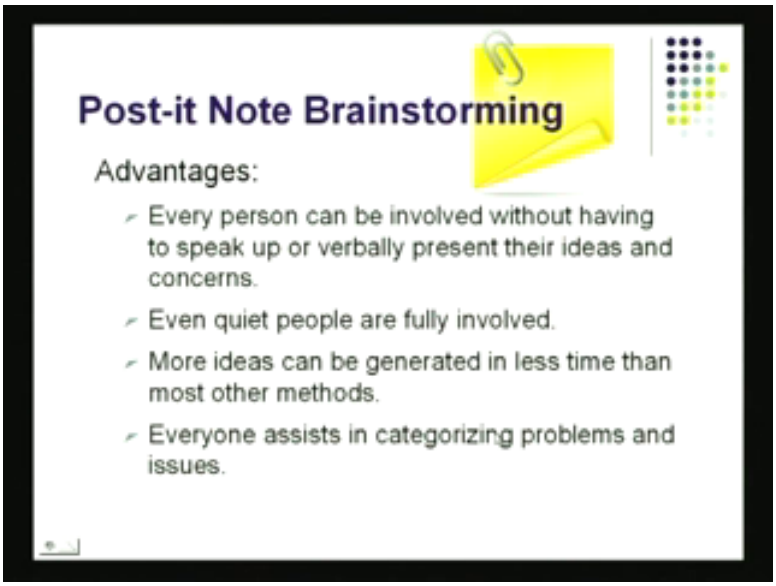

And you could use the, what we call the post it notes, you could do anything else. There are number of alternatives available and basically, what you should be able to do is, let the ideas pour and there are some steps that are provided here step one step, two step, three, and step four and so on and so forth.

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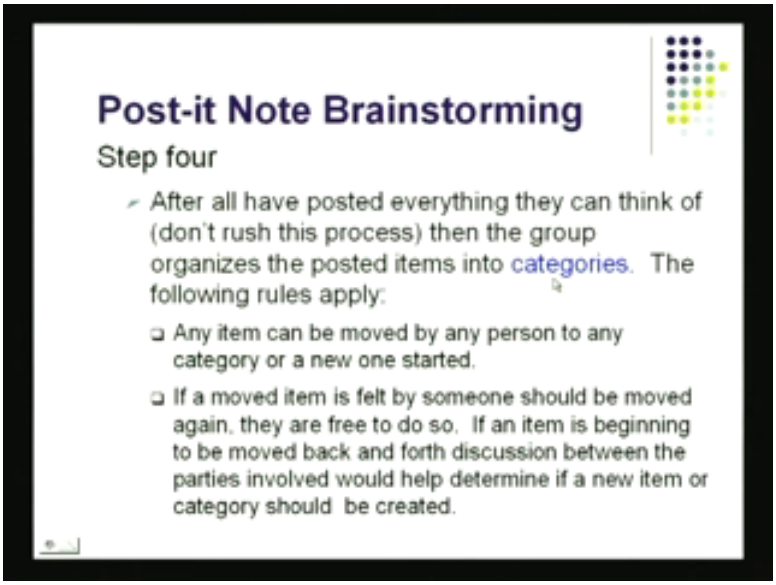

Eventually, the ideas to be able to sort out the roots to be able to get to the roots.

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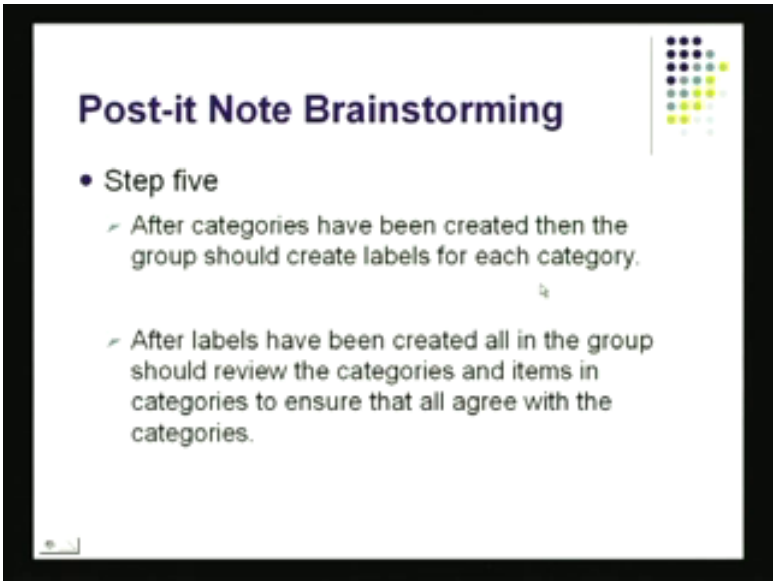

Once you got the roots there, you got a starting point. You can actually for now, looking for prevention in trying to reduce the occurrence itself or perhaps the impact of it, if you trace it down to the root, you got a chance you got a good chance there.

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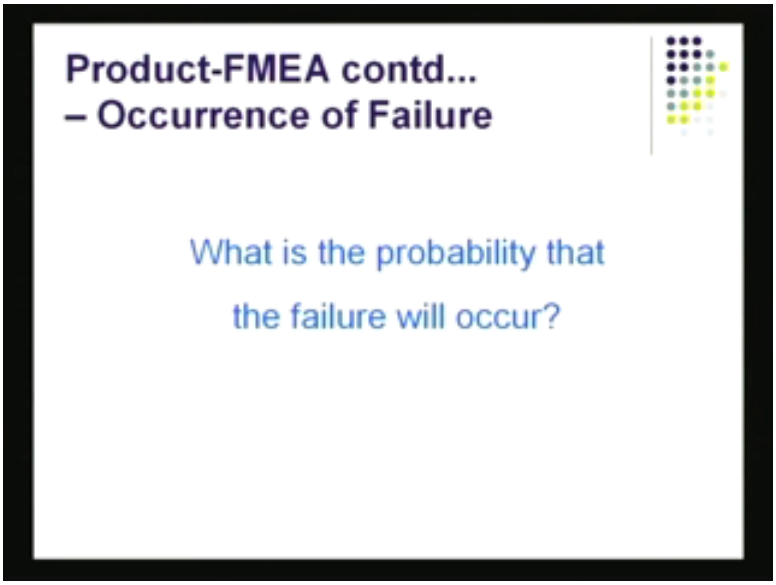

And, so based on it would be like one great way to get there. Now, that will give you the cause you also have to find out what is the probability that the failure will occur.

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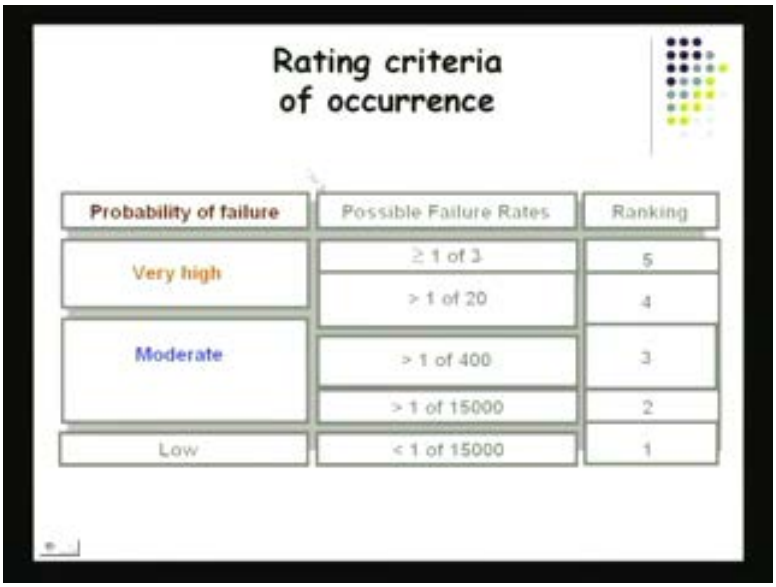

This is something that can occur at various different places, there could be a very high chance of failure in which case, the chance is something that to I have to worry about. So, I will look at the ranking and if it is very high that will lead to a very high rpm, and I want to give it some attention. I want to so basically, it is going to be helping you in try to prioritise the different action items.

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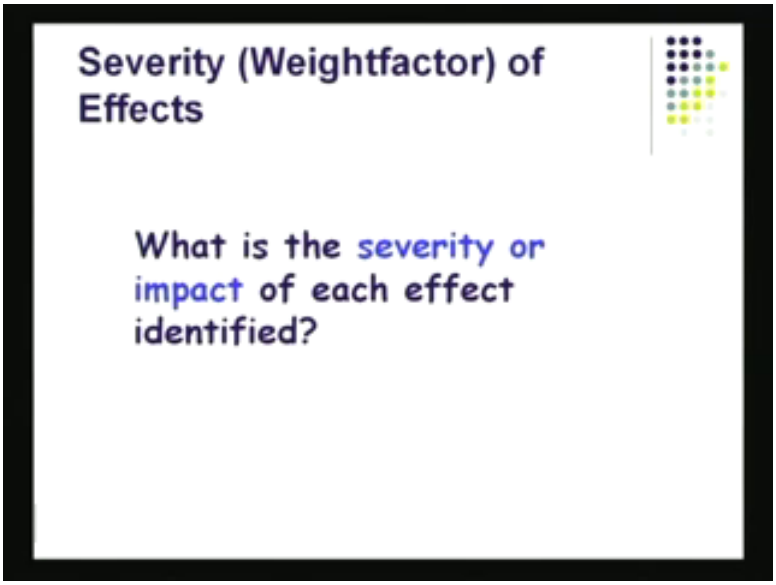

If something is likely to happen, if some failure is likely to happen please go after it do not leave it alone. And then of course, you have got to look at severity also and severity or the impact of it that can be done this way.

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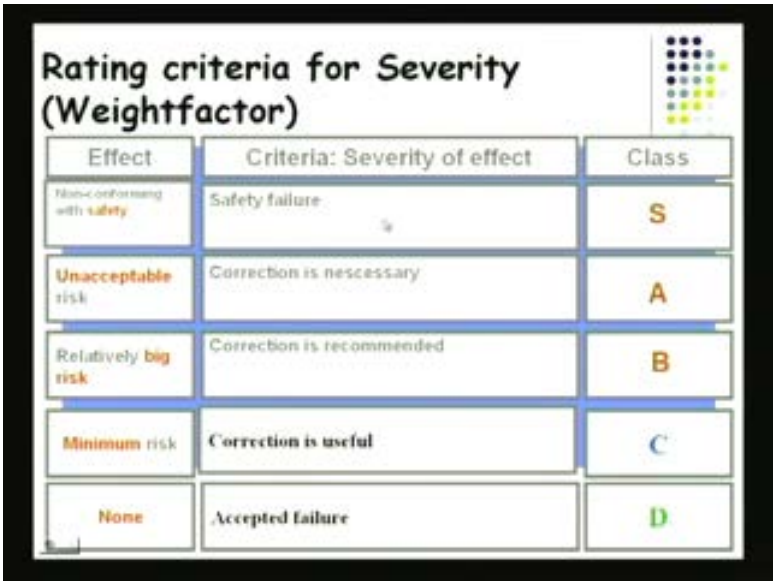

You look at the severity, if it is the safety failure, it belongs to class S; if it is unacceptable you know industry calls it class A; if it is a big risk then it will be a big risk and correction is recommended will be class B; then with minimum risk that will be class C; and if you are willing to live with it that it will be it will be class D. So, these are the different ways by which I categorize my severity. And of course, numbers could be tried here, I could probably say 10 for S; 8 for this; and 6 for this; and 4 for this; and 2 for this; with that I will have numbers.

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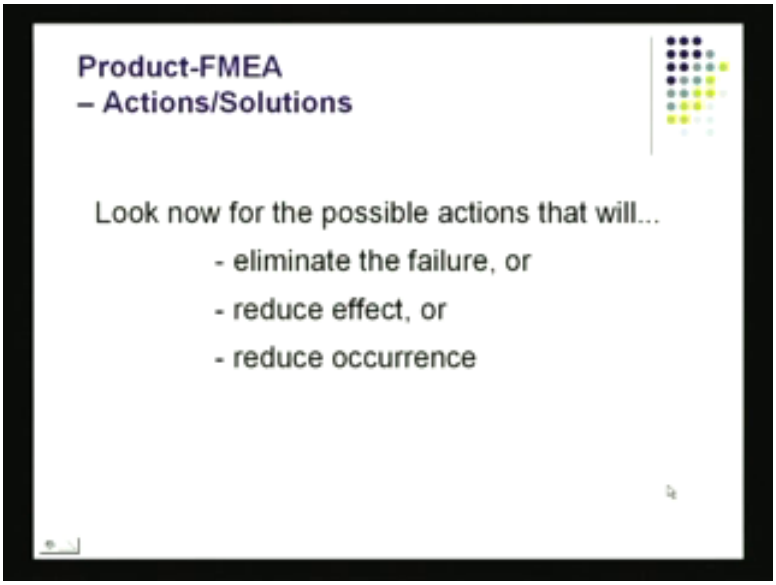

And those numbers come very handy, once I go out and I try to do basically, what we call rpm calculation. So, what are the various possible actions I'll be taking? If you look at the possible actions, I will try to eliminate the fact failure, or I will try to reduce the effect of it, or I will try to reduce the occurring. So, either I eliminate it altogether by taking some design action or by rectification action, what I try to reduce the effect of it; I take some preventive steps there or I will reduce occurrence. Any of these things if these are done, they are going to impact your RPN and that is going to be a big plus.

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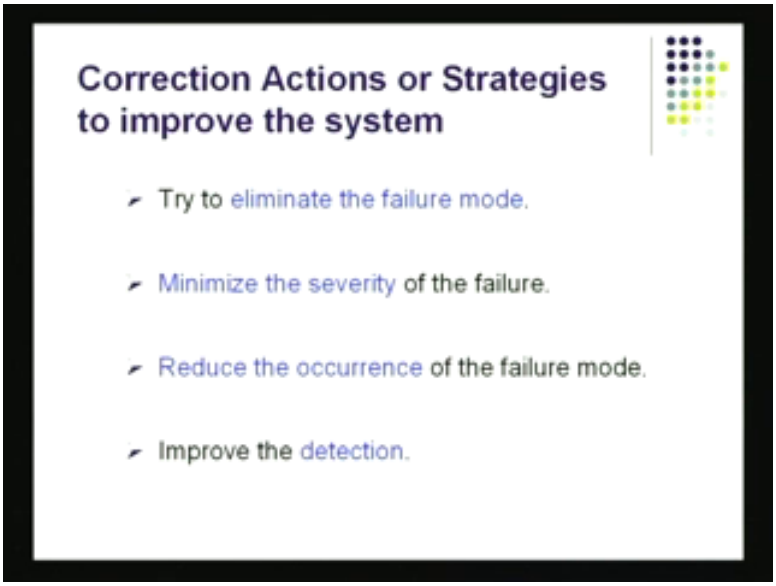

If you look at if you look at again, the different alternatives that we got, corrective actions we have got, when eliminate the failure modes itself that will side, just remove the root wherever the problem started with and minimize the severity. And this could be another way to try to reduce the impact, reduce the chance of it and improve detection.

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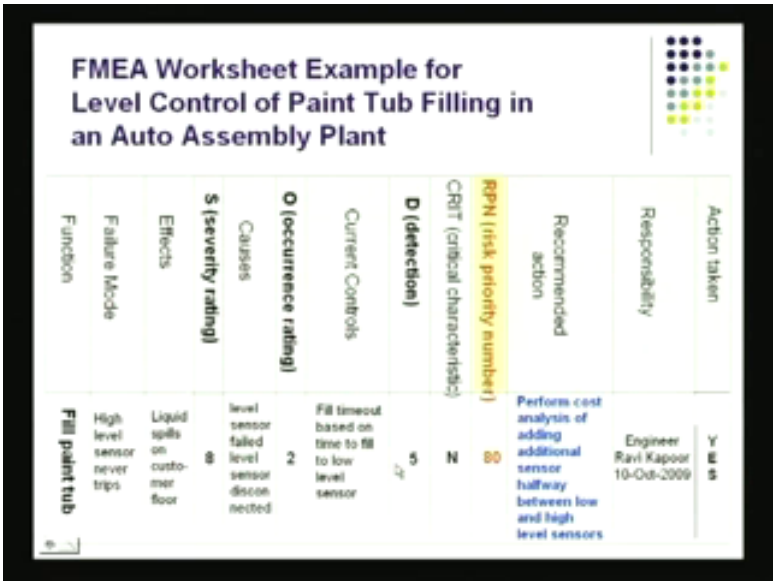

Any of these things if you act on, any of these fronts you are good to be gaining. Alone behold we are back with the worksheet here, and I see there this item 80. 80, this is the same paint tub filling problem and it is got a RPN of 50. Hopefully, the other failure modes have led to an RPN that is less than this. Therefore, this is one that should get some action, some action is planned here and this resulted from looking at severity, looking at the likelihood, and looking at deductibility. And this is non critical item so, I do not really have to work on it immediately. But, I it is something that I should take a look at and that is to assign to an engineer and they report you, yes he acted on 10th of October 2009 and he took the corrective action there.

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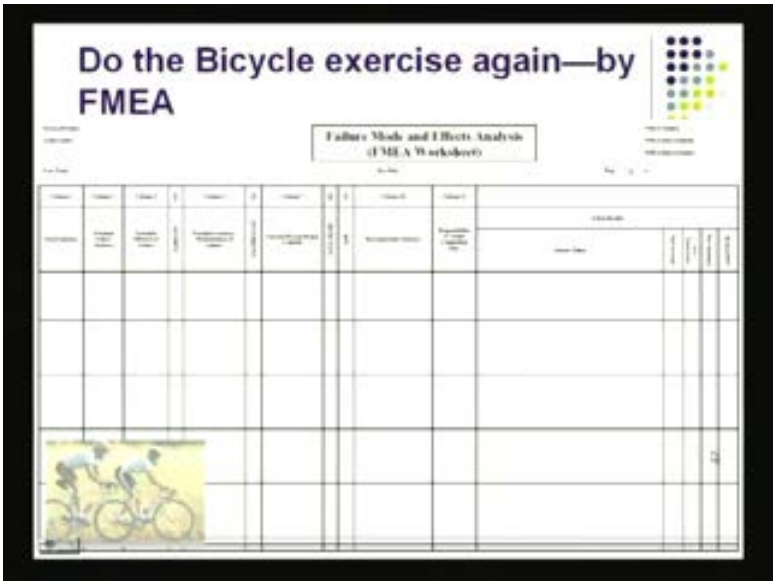

I have provided you here with a worksheet and of course, you will find worksheets, either on internet or you will find it in reliability books and what I would like you to try is again, going back to the bicycle problem there, we did an FTA on your bicycle. Now,

this time try to find out; can you do a FMEA, on a bicycle; on the total system as a bicycle. And, I just for one moment I would like to ask you a question and the question is this. Are the two wheeling's of the bicycle, as far as reliability goes, are they in parallel or are they in series? Please try to figure out the answer.

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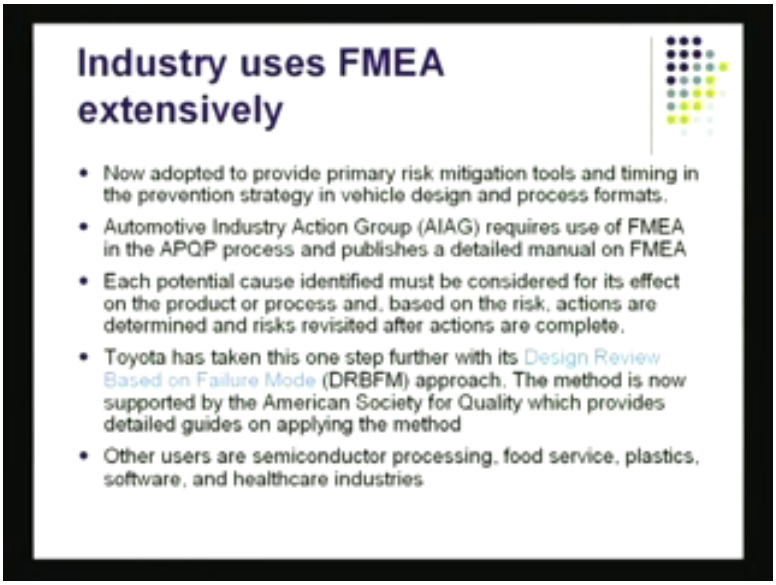

Industry uses FMEA very extensively and basically, you know this is something that is done very routinely and it is been prompted by the automotive industry action group AIAG. They have basically prompted people to do FMEA and you will be doing design review that is like something that is done, that is like another mode of doing FMEA.

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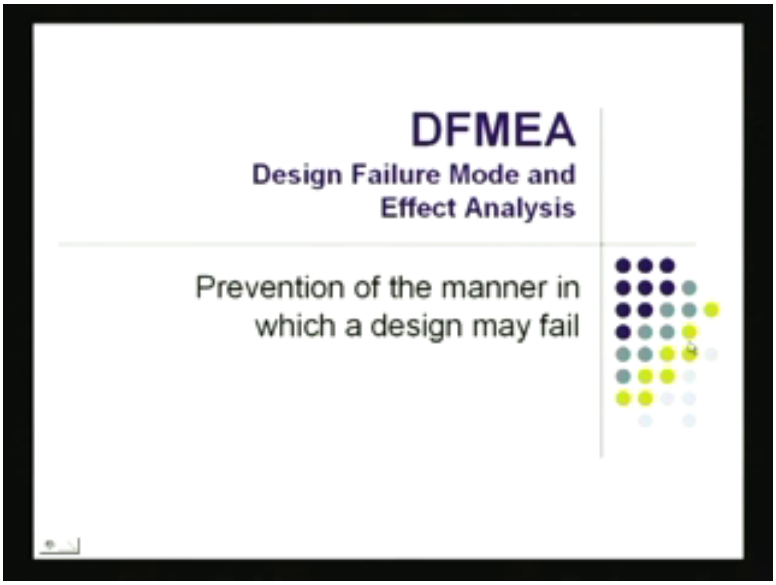

The design FMEA, this is leads right into our design failure mode and effects analysis. Now, we are looking at designs themselves.

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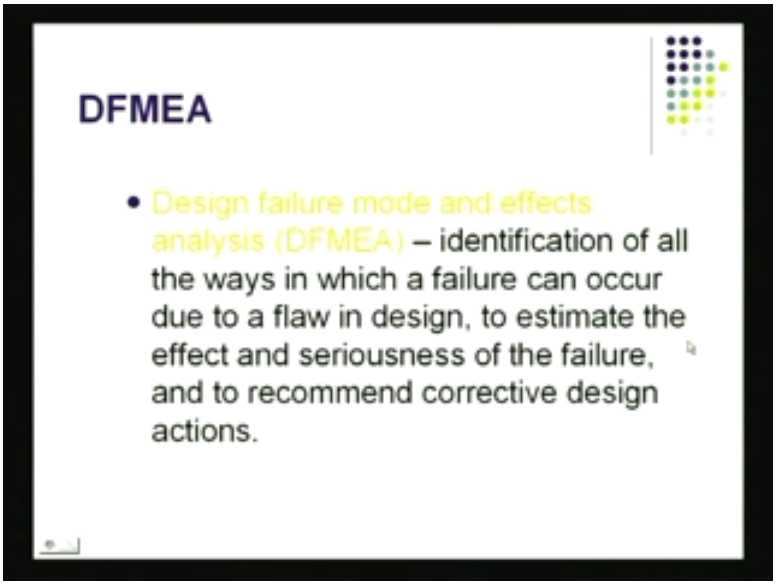

And we will be following the same routine that we did for basic FMEA. Identify all the ways in which the a failure can occur. And this of course, we are trying to do this, when we got the design on the drawing board. Estimate the effect and the seriousness of the failure and recommend correct action and the corrective action here is going to be modification of the design.

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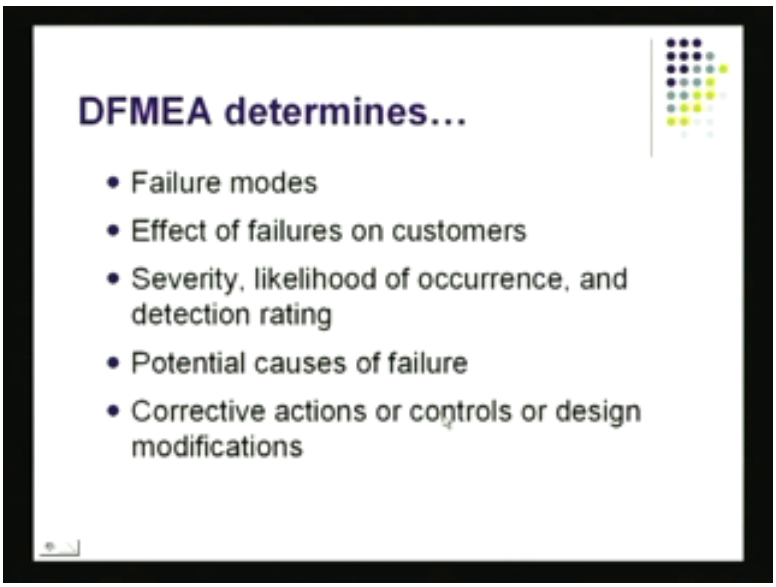

So again, design failure mode effects and analysis, this is going to be first, identify the failure modes. Look at the different effects of failures on customers for example, look at the severity, look at potential causes of failures and then look on modification of the design to try to eliminate this problem there.

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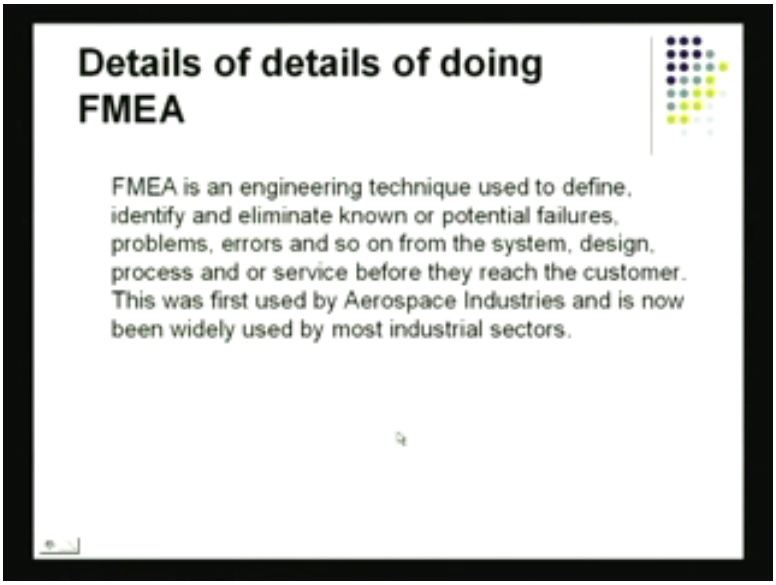

So details of doing FMEA, those are laid out in these different slides there. Again

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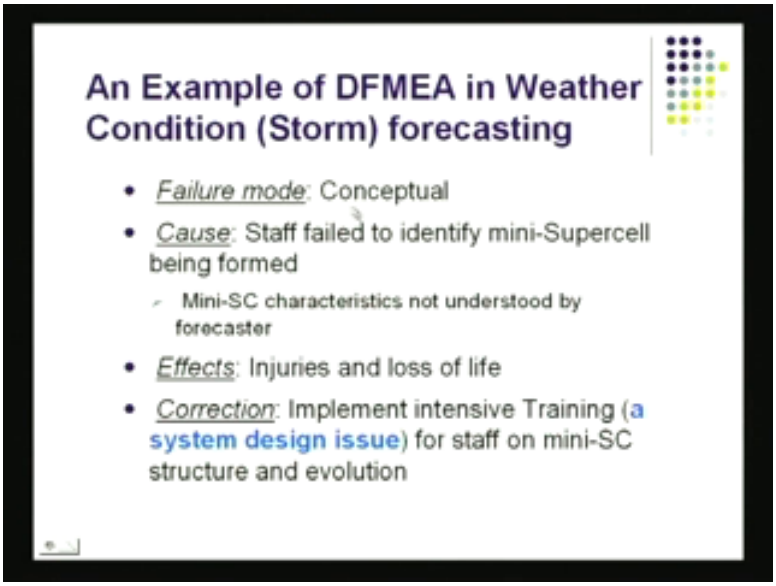

I have got the failure mode there; I have got the causes there; I have got the effect there; I have got the correction there; and I have got to make sure that, this is done in a team manner because, it is not so easy. Let us take at this example; let us take a look at this example. There was a particular storm; there was a huge storm that even brought a tornado with it.

Unfortunately, the people who were watching this storm, they failed to recognize something called the mini super cell that was being formed in the storm system. They failed to recognize this because, there was a shortage in their training and this is something that became a major issue. There is a consequence with this. Yes, there was some loss of life because, it was not a very tinny winny storm. It turned out to be a big tornado and led to loss of life and property. Although it was not, fortunately not very big

but, it was something that people should have caught early on and this was based because of lack of training, lack of comprehensive training. So, that was pointed at something that was a, if you look at the designs of the total system, what is the total system here? It is the man plus the system all the communication devices and display devices and everything else and the sensors and so on and so forth, and the data analysis program and so on. All those things together they make it the system.

The in the final at the end of the day, it is the person who makes the decision and if he is not competent enough to process all these things, that could lead to a failure and this was traced. This particular failure was traced to a problem that occurred with incomplete training of the person who is in charge of forecasting storms.

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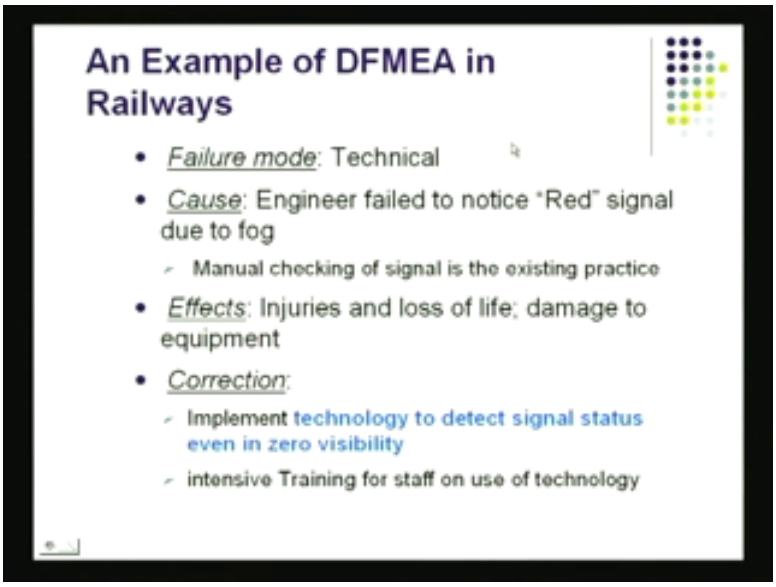

I, here is another example of a designed effect. An engineer, this guy he was riding a train and he failed to notice a red signal due to fog and he this led to a major accident loss of life and so on and so forth. Now, this led to injuries and loss of life and of course, damage to equipment. So we saw the cause, the cause was that the person could not see the red signal and this was done by manually checking, he was looking out and he would check that way, whether the signal is up or down or is it red or is it green or something.

He just could not see anything because the fog there and he might be coming from a different line, he might not be familiar with that area there. So, he might not be looking out to see which signal, you know from far enough distance to be able to stop the train or slow it down that he could not do. The collective thing, what we hear to do, not depend on manual detection. Try to see can you provide some technology where by, this signal up or down; signal green or red could be detected while going there. This is something that we should be able to do this is something that we should be able to do and what we should really do is, as much as possible, we should try to see if we could prevent problems like this.

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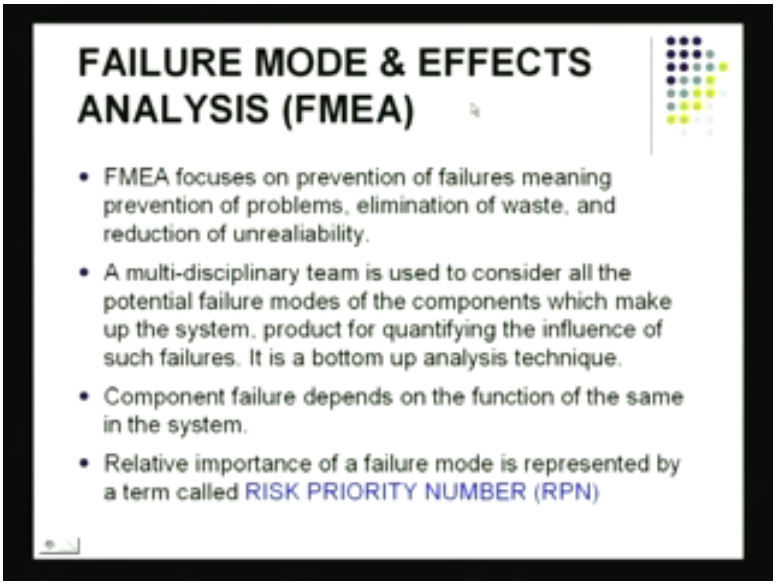

The bottom line is going to be again calculation of the RPN's so, this is something we would like to be able to do. We would like to work out the components of the RPN and again the risk priority number. It is made up of the severity, there will be a rating, there will be a number of the probability of the event taking place and the detection capability. These three things, they must come together and they should give you; if they give you a high RPN, that is a serious matter, you got to take some action there. You got to take some corrective action there and these this comes out, these numbers come out as the result of this FMEA analysis.

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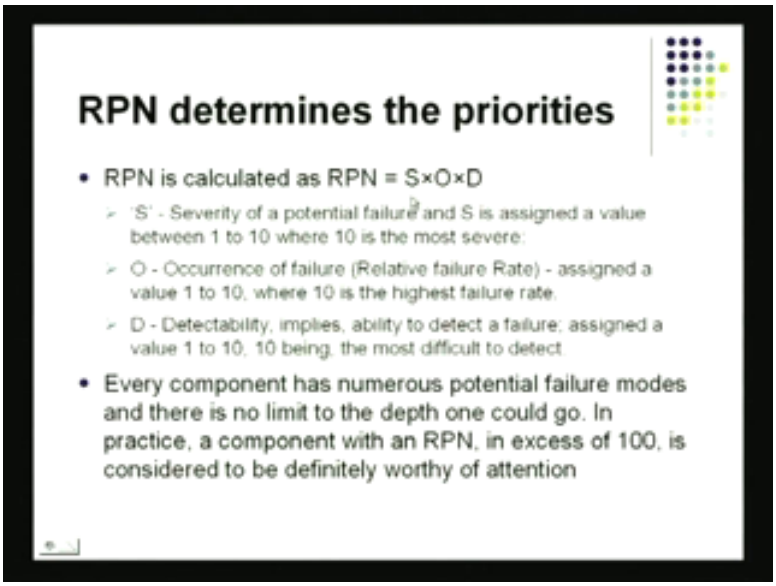

So, I have got here the same formula there. S is the severity; O is the occurrence of failure, which is the probability; and D is the directory detection capability. These things together when they multiplied, when they are multiplied they end up with RPN. RPN is the risk priority number and that basically, if you got RPN it is on different actions there.

You should really go with the RPN that is going to be highest RPN. First attend that point, then go to the next one then go to the next one and so on. And we each of these RPN's leading up to some corrective actions that is really what we are after. So, doing FMEA's in such a way that, you are able to find these high impact, high latitude high latitude and low detection capability items first. Once those are taking care of, then you move down to the next ones and so on and so forth. This is something, we should be able to we should be able to do without any trouble at all.

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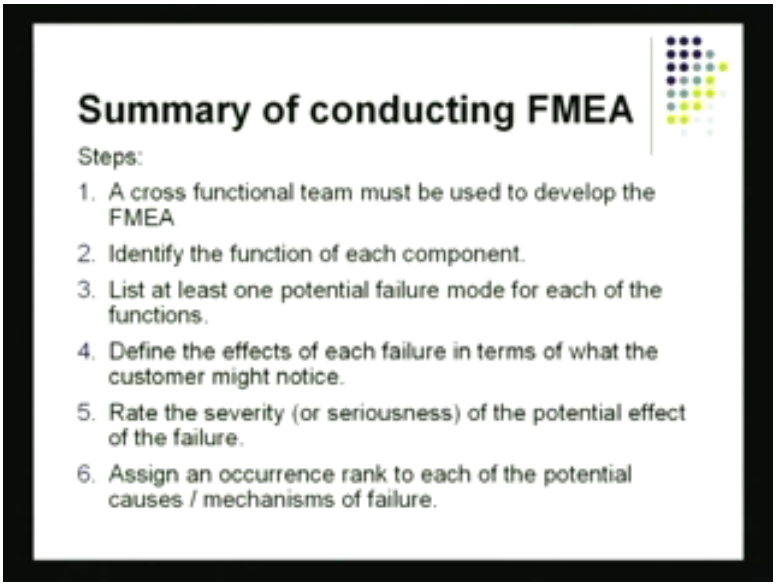

If I am if I am doing a FMEA; so, the summary of conducting FMEA across functional team must do FMEA, identify functions of each component; find try to find at least one mode of failure; one mode of potential failure; define the effects look at the severity and look at the detection capability. This is something that you got to be able to do.

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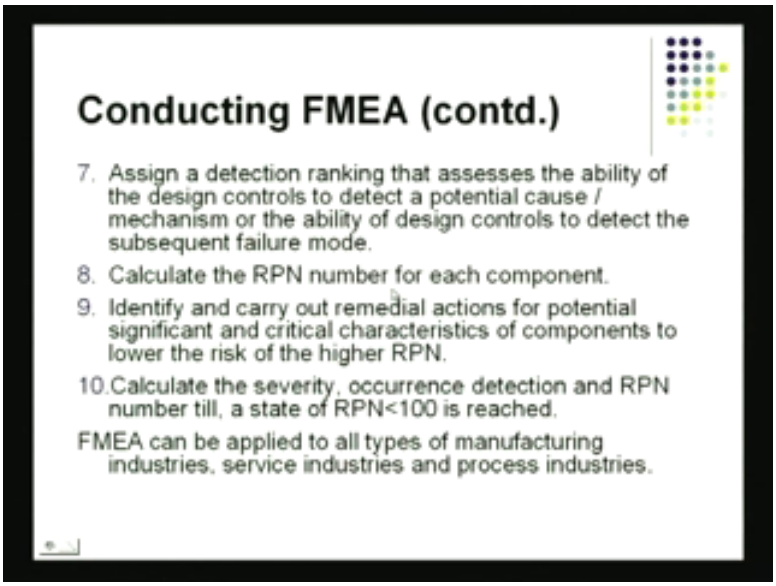

Once you have done that, you can calculate a RPN number. RPN would come very handy in term of prioritising the different numbers there. Once you have done that, you then got to be creative, you got to then come up with solution.

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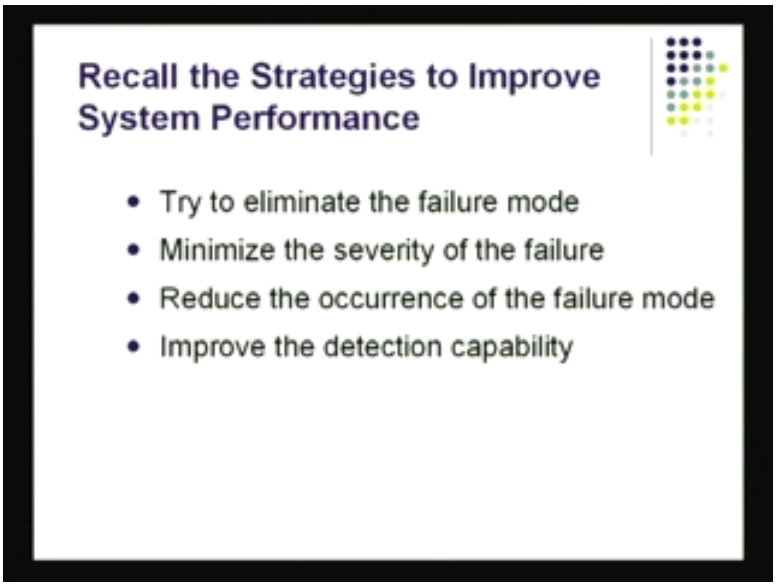

And solution would come for engineers. To try to improve performance, how do you actually do this? Either you would like to eliminate the failure mode itself, if somehow something is there that breaks down because of that.

Minimize the severity of it, that is also something that is like another course of action that is there. Reduce the occurrence, reduce the likelihood of the probability of it and improve detection capability. Like in our case, for the railway signal it was not be able to see the red light, the red signal that was like the problem there. So, you try to improve that by putting in some technology that will probably. There might be some sort of a not necessarily audio but, some other kind of signal coming through and that should be detected automatically. In addition to whatever the person is trying to do, that should be there.

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But, some failures are more preventable than others and this we have seen so many times.

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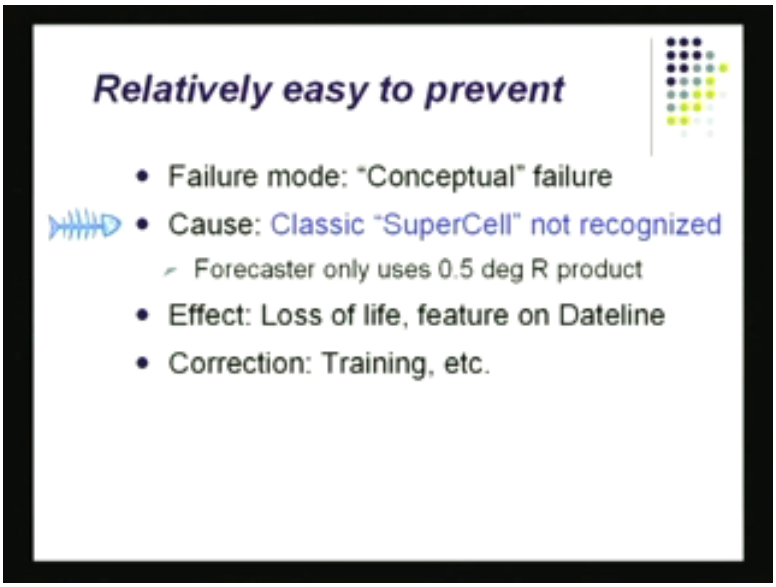

Let us take a look at that warning system again. Notice here, we had that supercell, supercell was formed in the storm system and this led to a conceptual failure because, the person did not have enough training to be able to do it.

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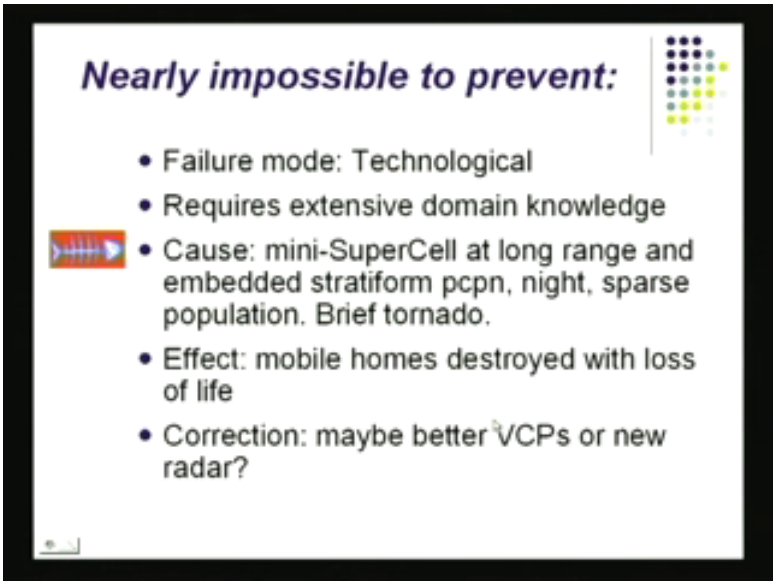

How could I change that? I could really change that by changing the technology. Perhaps, I could use a different kind of technology and not being dependent on a person not being dependent on a person to be able to recognize that because, he is doing a lot of signal processing in his mind. Through his eyes, he is trying to detect very some very fine things, should it be left like this? I will look at the consequence, look at the loss of property loss of life and look at the tremendous cost that would lead to. I could perhaps have some great technology and this is something, we should all try to do. This is like one place, which is not very difficult figure out but, I should be doing right, you just should not hesitate to take that corrective action, that is the message.

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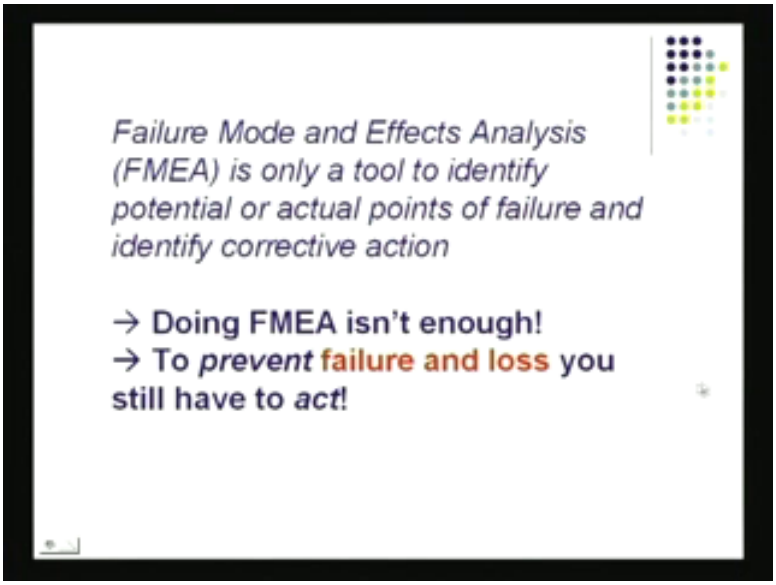

Basically, doing just FMEA is not enough, you should be able to take the prevent the failure and loss. This is something, for which you got to act.

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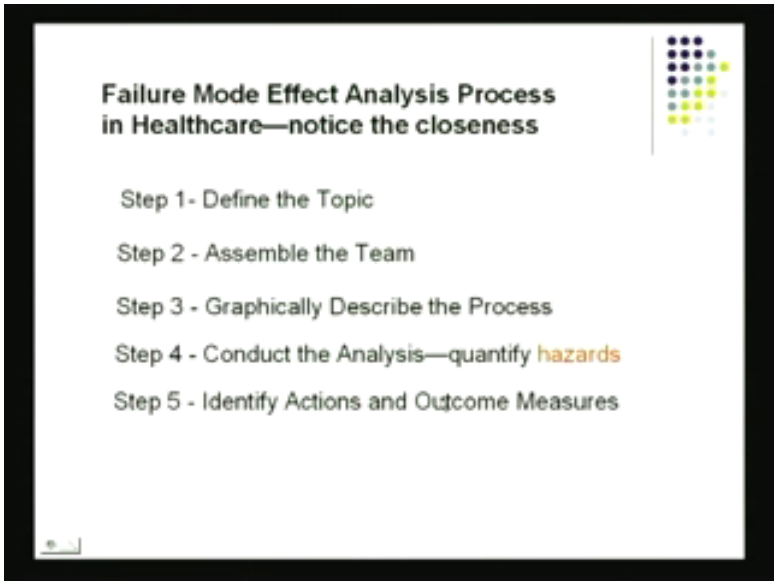

And that is something, that comes along very handy once you try to do this. In certain situations, you will try to quantify hazards and I will give you an example.

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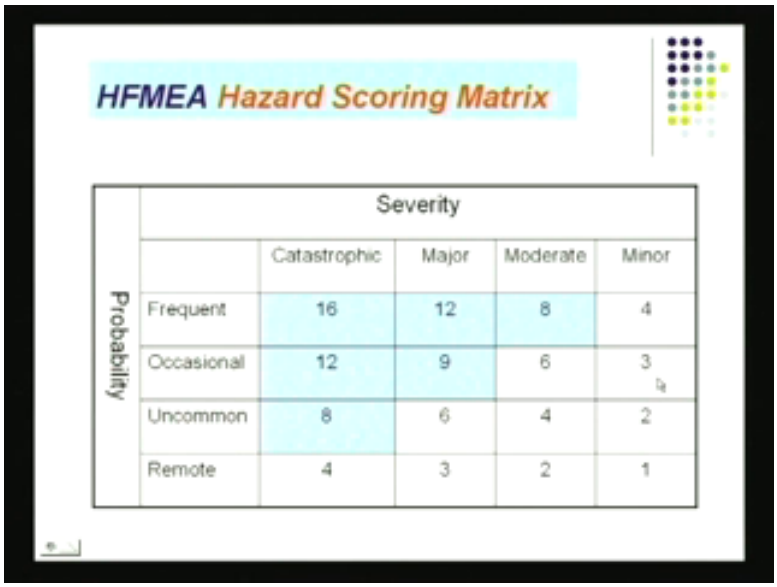

If you look at the hazards scoring matrix; this is like another matrix; that is also very similar to what we did. We calculated RPN and what this guy is doing; what this matrix sub cost is doing. It is again, it is ranking the severity in terms of the consequences; catastrophic impact, major impact, moderate impact, minor impact. So, you got some ratings there and then, you have got probabilities. And if you frequent, it is catastrophic, you give it this and if it is frequent and major, you give it this number and so on so forth. And if it is, if the probability is pretty remote pretty in frequent in some minor sort of severity, you give it number 1.

So, here I have got items here that actually have a hazard scoring that is, 16 or 12 or 9 or 8 and so on. If an item ends up if a FMEA leads to this sort of scores on the hazards

scoring matrix, this is like another approach. In place of doing the RPN, you could do it this way and you would again end up with very similar analysis.

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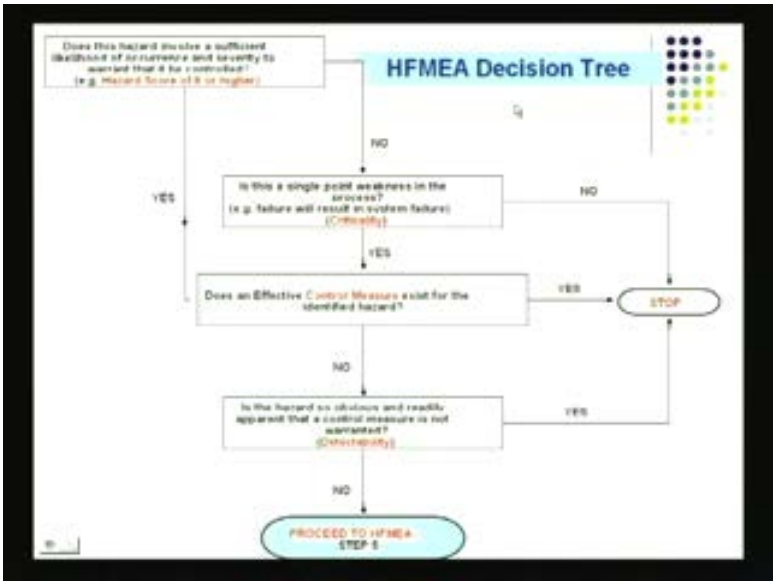

Here is an example, which is of a you know which is using decision tree. So what it says is, let us say first you have done this and then you got a number there. If the hazard score is 8 or higher, you have moved this way and you try to sort of see. Does a control measure exist for the identified hazard? if it is, you got your action done. You do not really have to go further just activate that action there. If it is not then, you see if you could improve the delectability of that particular thing there. And then, you proceed to what we call a hazard guided FMEA; this is something that you should be doing.

If you have good detection capability just go ahead and act, there is no real issue there. If suppose, it is not a high rating; it is a rating like 3, 4, 5, 6 and so on and so forth. Then, you come down this branch and then, you ask yourself the question, is this a single point of weakness? If it is yes, then you probably go through the other boxes and so on. If it is not, you stop right there. If it is not a single point of weakness, you stop right there. Stop basically means, you got to move on now to other actions, that are possible there. So, what I would suggest is, try look up some references on hazard guided, failure mode and effect analysis; here is an example.

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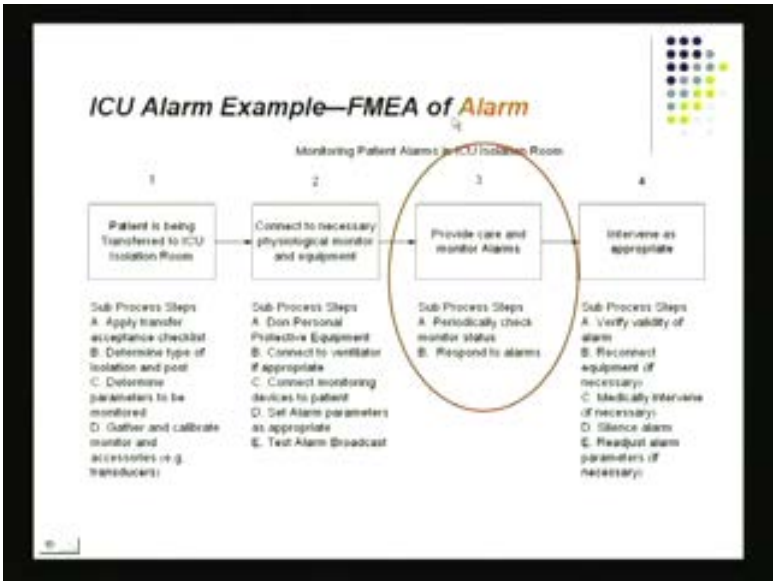

You know this is, this example is taken from the healthcare industry and it turns out that, there are certain patient alarms, which are you know they are connected to the patient. If there is patient in ICU for example, you do not really have a doctor or a nurse sitting there round the clock and watching every movement of the patient or his BP's or everything is changing there. That is not something that you do but, you got alarms, you got the body alarmed in various ways and those alarms trigger action. So basically, what we do is in several places, would like to probably provide care obviously and monitor alarm. This these monitor alarms would lead to the kind of action that we would like to see. We have got to make sure these alarms function, the alarms do not themselves break down. For this, I am probably have to go into this a little bit to make sure that the alarms are functional, I can rely on those alarms. I have got three there, action item number three there. 3A will have one consequence and 3B will have another consequence. In 3A periodically, I check the monitor status to just to make sure that, you know the alarm is active and the alarm is still looking at the personal there and so on so forth. And of course, the other part is the respond to alarm that is also something I should be able to do, once the alarm is there.

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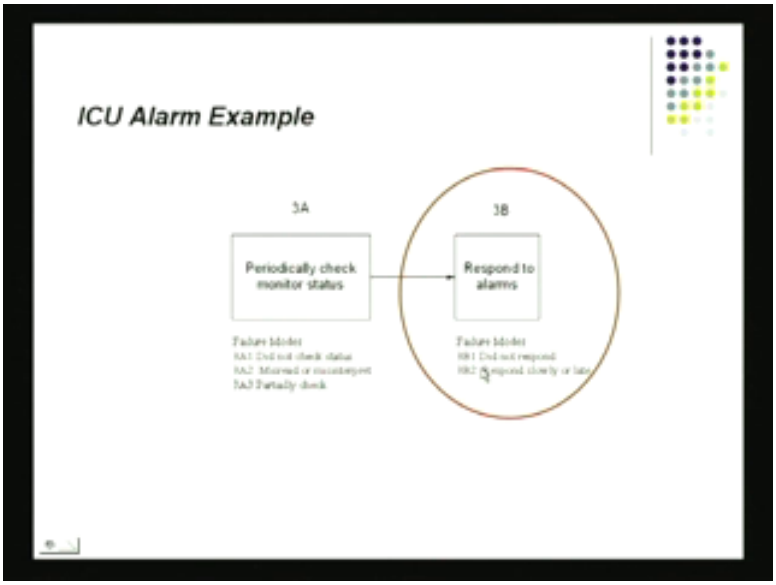

So, periodically it checks the monitor status, so has there been an alarm? And now, this step could fail. If the nurse fail to check this status, that of course is something there or misread or misinterpreted the alarm, that came along or partially checked. Any of these sins could lead to a failure there. Obviously, I would like actually to get to this point, when it is like I respond to alarms and what are the different ways? Even if there was an alarm, the person probably did not respond. This happens once in a while or you responded slowly or too late and by that time the patient was out of control. I mean this is like something, we should be able to do.

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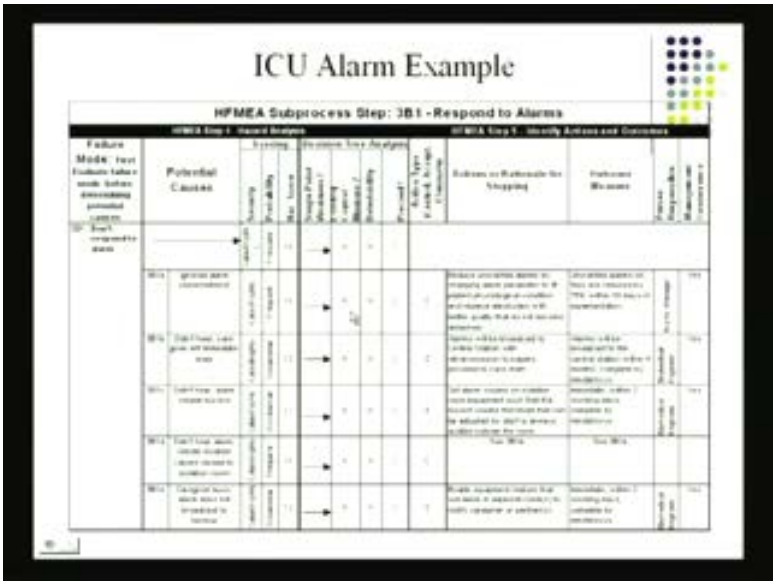

Now, to try to get into this, you do an FMEA. To try to prevent those sort of occurrence, you get into this. So, I have here 3B 1 which is like, if you look at the first there 3B 1 did not respond. Why could it not respond? Ignore the alarm and did not hear the alarm; or the alarm volume is too low; or it was in a remote location; or probably the caregiver was

busy. Therefore, you know just missed the alarm. And you do exactly what we did earlier and you come up with outcomes you come up with outcomes and action plans and so on so forth. So we are also doing here, what we had done earlier; we are doing something very close to FMEA, that is what we are doing there.

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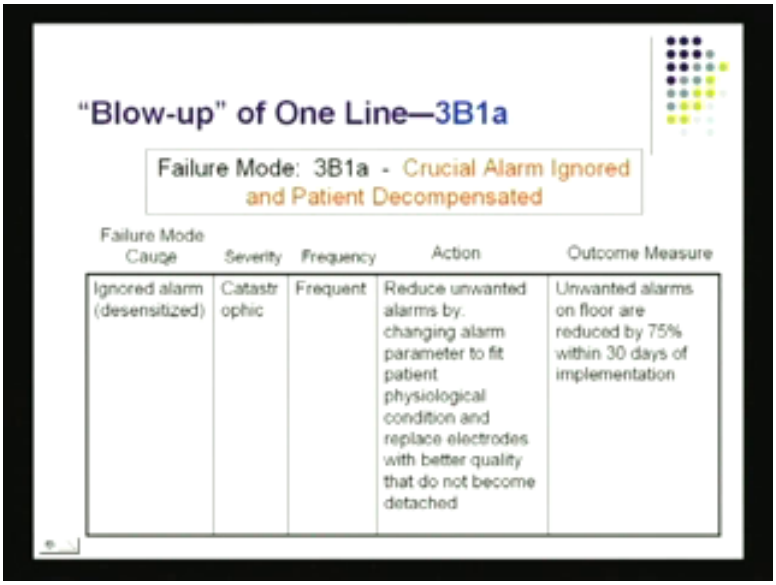

Here if you see, I have got the failure mode which is the cause. Look at the severity; look at the frequency; and look at the actions; and look at the outcome.

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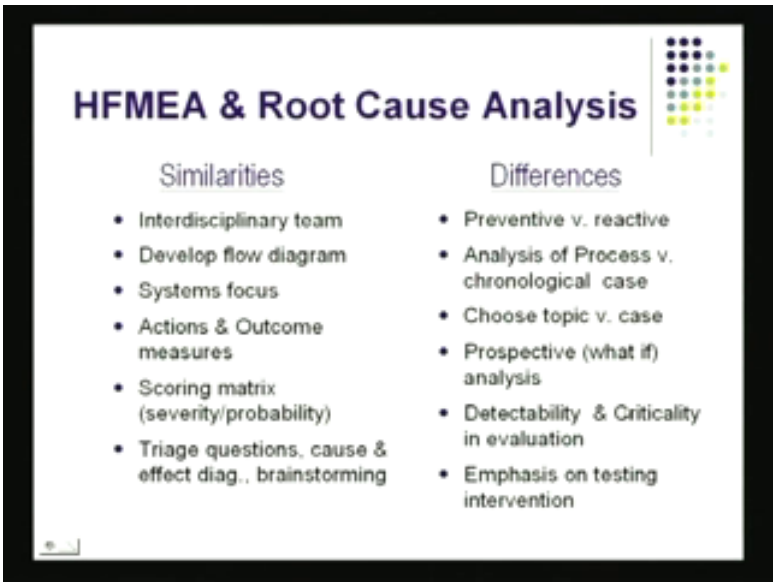

These are exactly the same that we followed in the earlier case at all. Now, there is some slight differences between root cause analysis and so on. There are some similarities in there, some difference is there. People tend to prefer one to the other and it all again depends on the industry. Engineering people, they tend to go by FMEA and healthcare people, they may go by the hazard FMEA. That is like something that is there.

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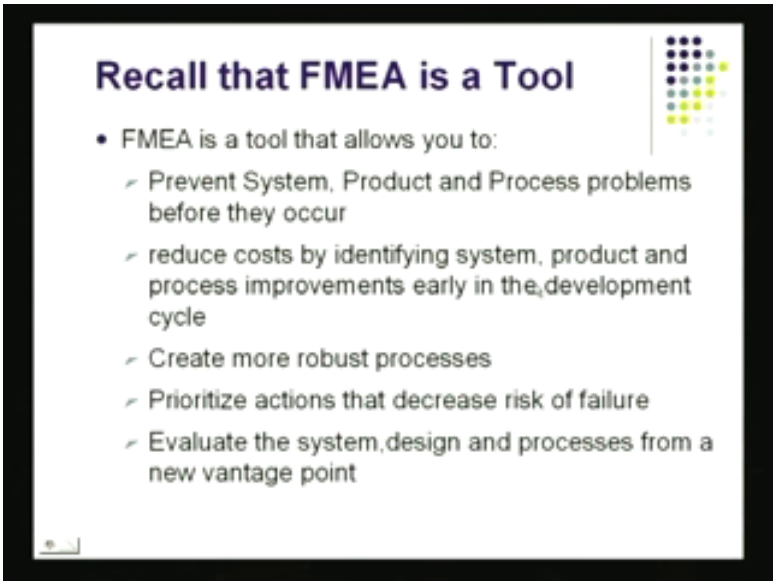

We got to recall that FMEA is a tool. It allows you to prevent basically system product or process problems before they occur. FMEA reduces cost by identifying system product and process improvement opportunities in the early development cycle of the product itself. And it creates a more robust process. That is something that it does, it prioritize actions to try to decrease risk or failure.

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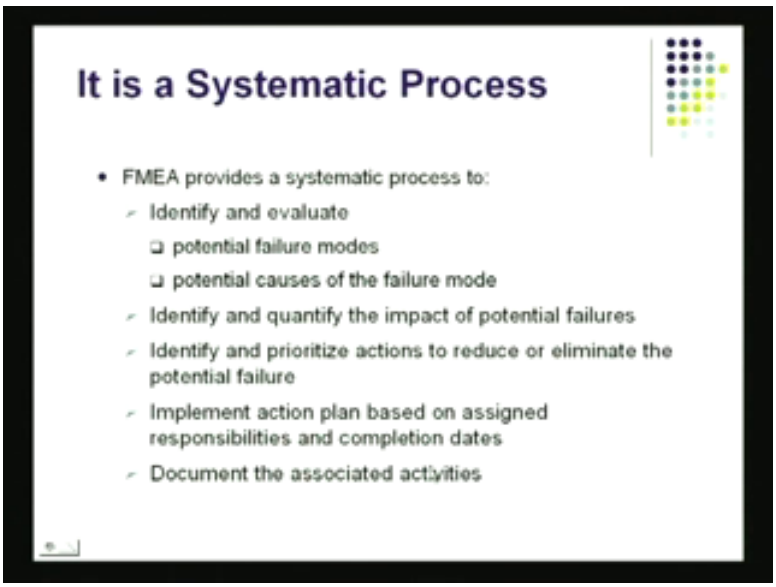

And, it also helps us evaluate systems and design from a new vantage provide. This is the point of view of trying to be take a vantage position of prevention. This is something that we try to do. FMEA is of course, is a systematic process and we have gone through the steps earlier and so, you would basically try to evaluate, you identify, you evaluate, then you try to quantify, then you try to prioritise, then you plan on some actions there and it document the activities.

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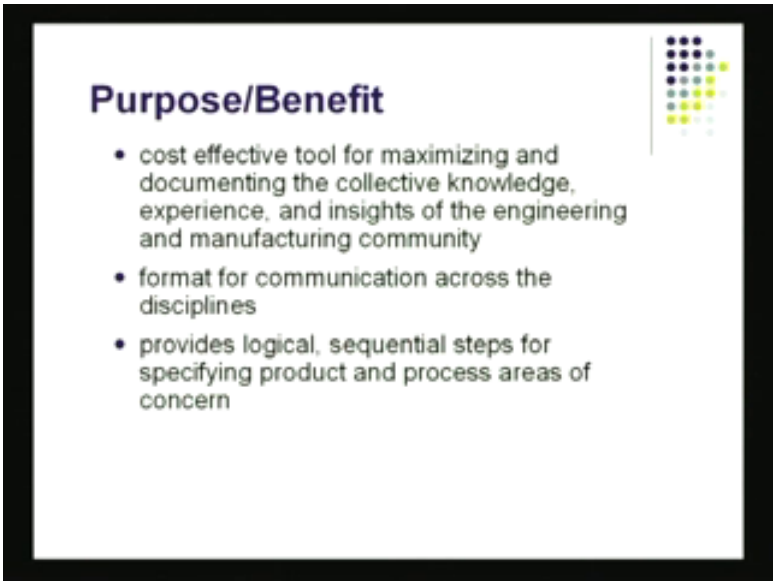

So these can be followed up later on. Purpose of benefit that of obviously are pretty major benefits of doing FMEA. This is something that is because of its logical nature and it is done quite frequently it is done quite frequently to be able to take care of this.

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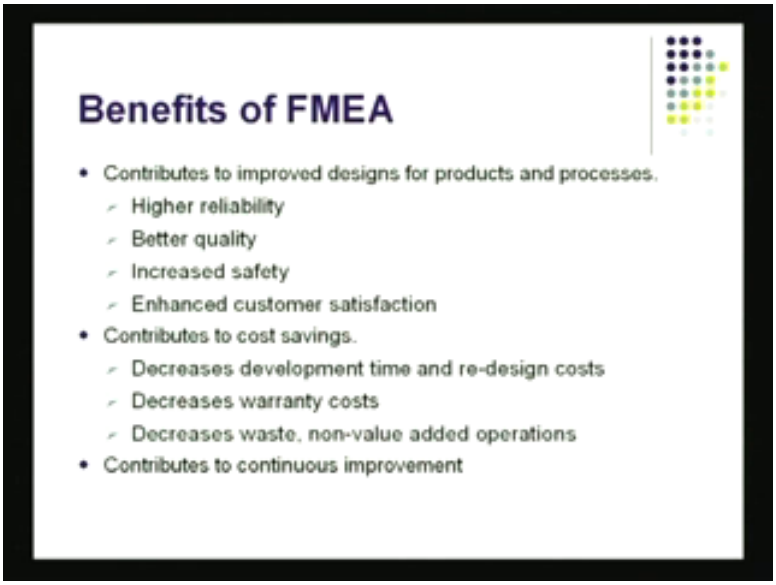

Benefits of FMEA again, I have repeated this; I have mentioned this before; I repeated again. It leads to higher liability, better quality, increased safety and as customer satisfaction. It also leads to cost savings; it also leads to what we call continuous improvement.

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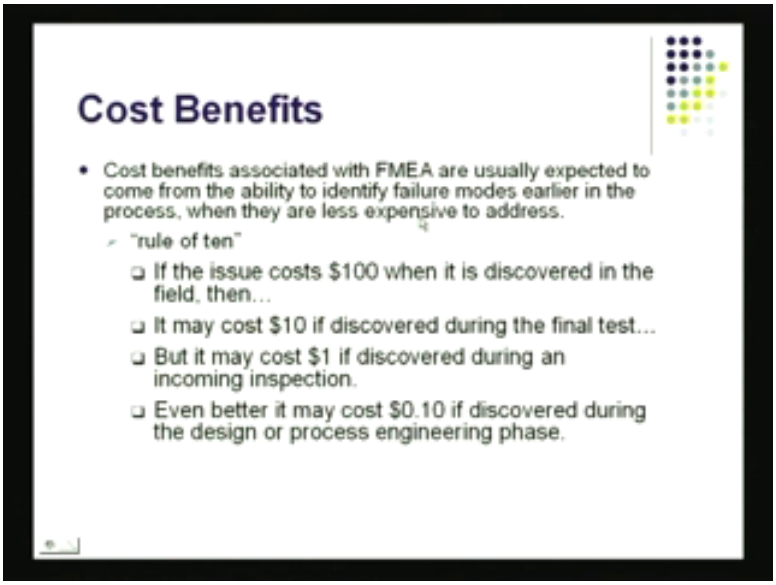

And there are some examples there are some examples there when it says, if it cost 100 varies discovered in the field that is a pretty high cost. It may cost dollar 10, if it is discovered during final test, these are like the product development life cycle stages. It may cost only 1 dollar, if the problem is discovered to an incoming inspection, this is like before you put the took that part and you put that assembled in a complete system there. So looked at your transistors or the chips and so on, before they entered the system. And it is even better, if you can do this, all this, right of the design stage itself. So start your design, start your FMEA right at the design stage itself.

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This is called DFMEA. What are the tools available to be able to do this? There is benchmarking available, there may be other people who are doing this job better. Customer warranty reports that can lead to failure indices and so on so forth. Design checklist of guide lines, field complaints, internal failure analysis, internal test standards,

lessons learned, returned materials report, expert knowledge, and certainly warranty service; these are the sources from which you can find out how things, how different things can go wrong; in what modes do you fail; what is their impact; what is the likely hood. So all these things can be found.

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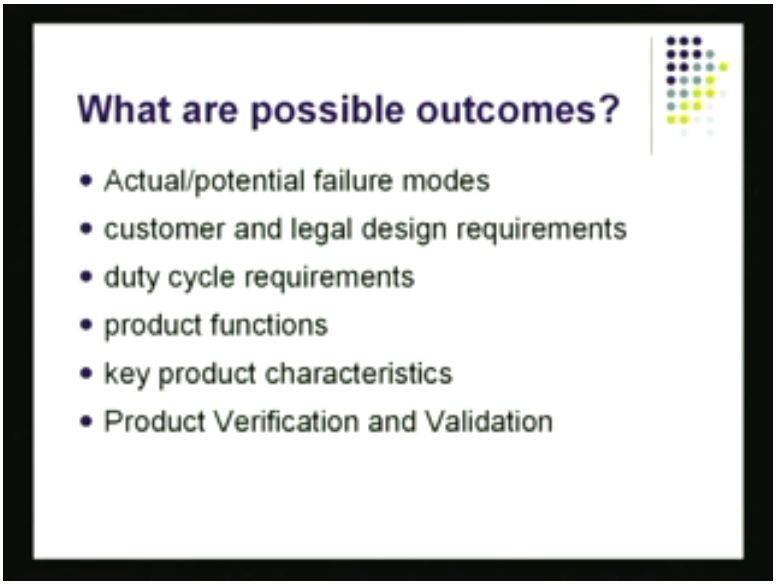

It you have got a good date, good database. What are the possible outcomes? What if you would do FMEA? You can discover the failure modes and it can lead to meeting certain legal requirements that also can be there, due to cycle requirements can also be impacted. Product functions obviously can be infected by doing this. So the key product characteristics those can be enhanced by doing this and certainly product verification and validation.

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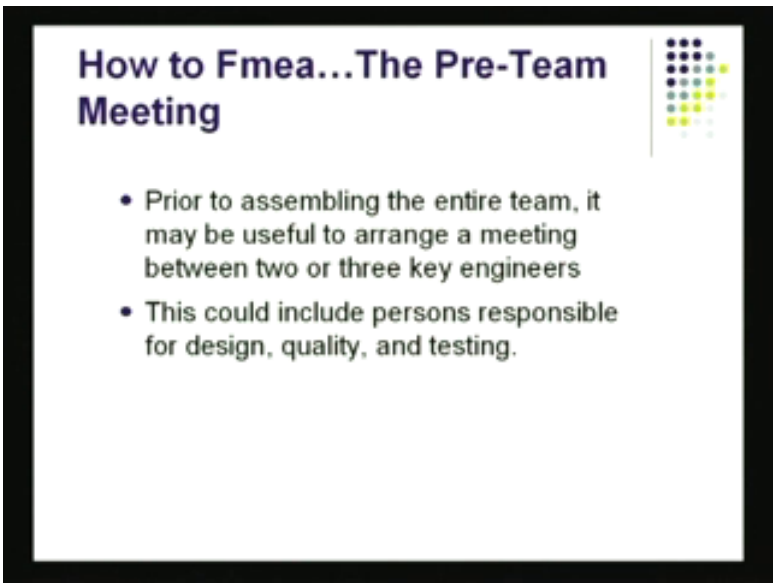

Validation is the actual use; verification means, it confirms to specs. And the of course, if you are able to do FMEA, you got do your PT meeting, which is like guys would be sitting around and they would be basically getting briefed on it.

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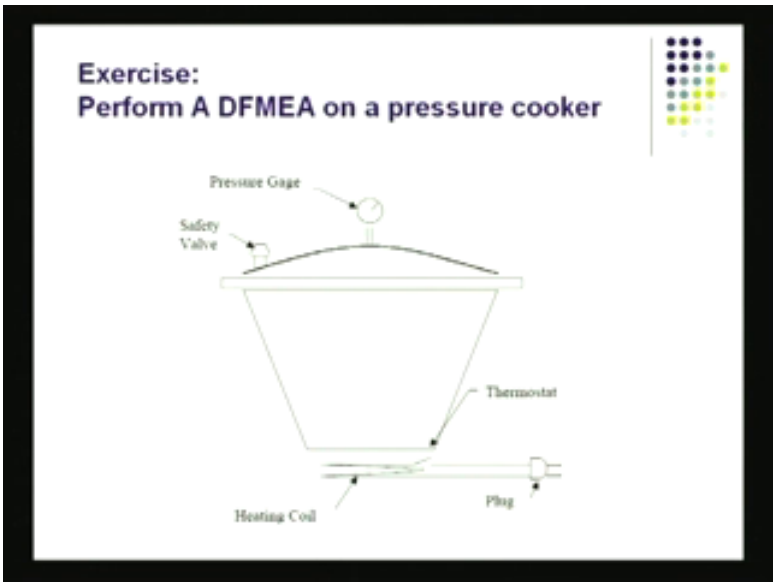

And here is the little example; a perform DFMA, so the team has been now looked asked to, we are trying to design a new pressure cooker and what all things could go wrong with this.

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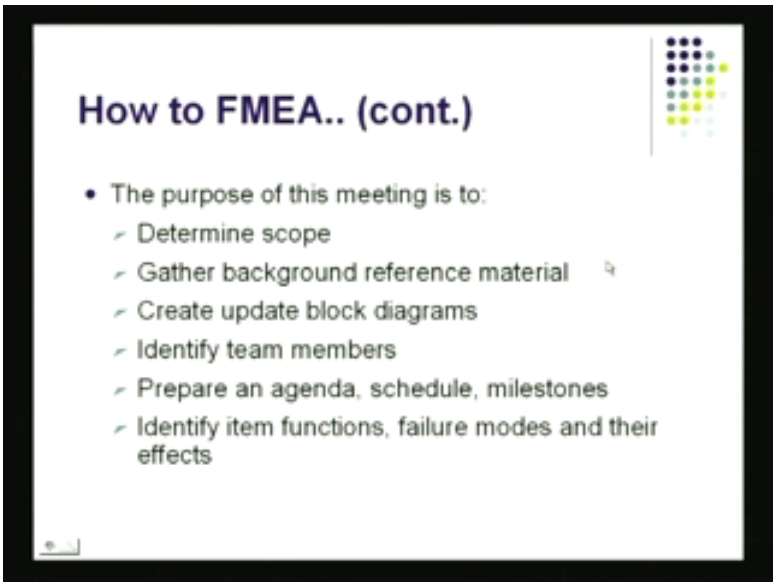

And for that you will start your basically approach. Determine the scope what is it that we are trying to do, gather background, reference material and so on so forth. I am going give you one or two illustrations on this. Create block diagrams so it is easy to understand what the process is; what is actually going on; identify team members, prepare the agendas, schedule a milestones and of course, identify item functions failure modes and the effects.

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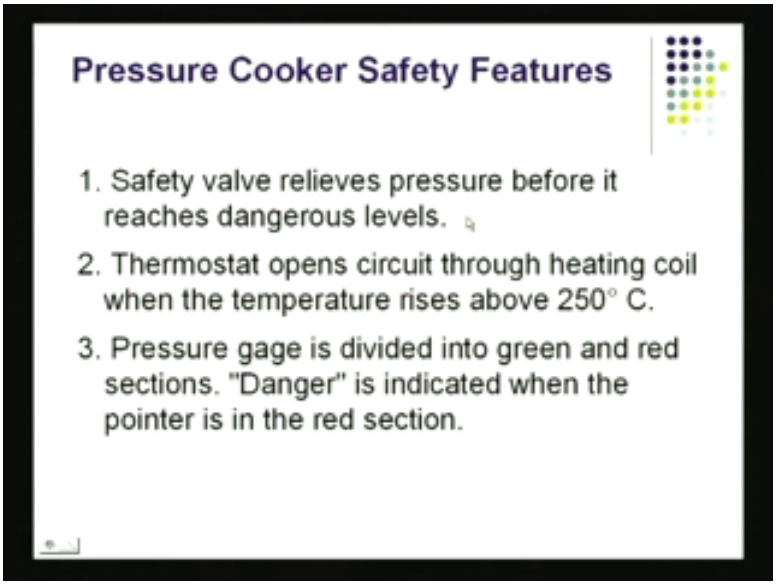

This something we should be able to do. For the pressure cooker, safety valve releases pressure before it reaches dangerous level. This could be like one, this is its function. These are the safety function though it could tail. Because of if this, for some reason if the safety valve does not release that could lead to major explosion. Thermostat open circuit through a coil before temperature rises about 250 Celsius and this also is a dangerous situation.

So the thermostat so, the safety valve could fail or the thermostat could fail or the pressure gauge, it is divided into green and red areas and danger is indicated when the pointer is in the red section there. But, there could be a problem there also, you can actually see three modes of failure right away.

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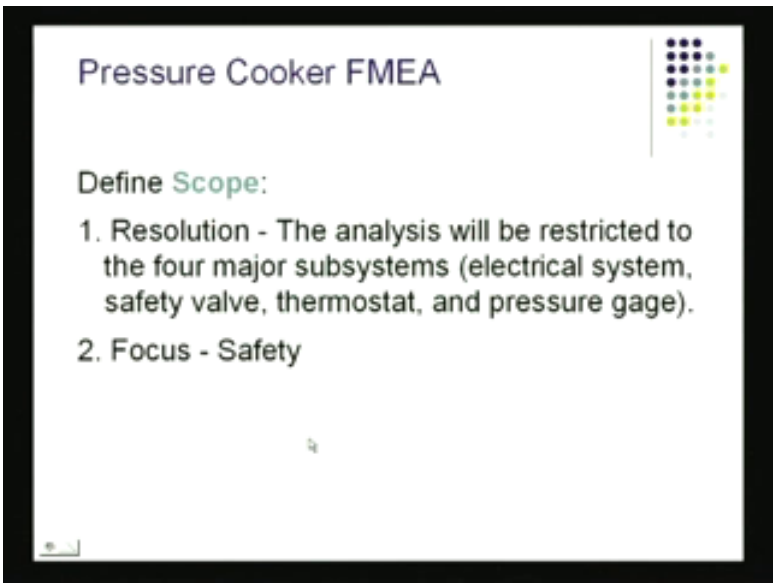

Define the scope; that means, let us take a look at these systems there and you could look at the electrical system or you could look at the electrical system or could look at the

safety valve thermostat pressure gauge whatever you want to focus your, your focus is going to be safety.

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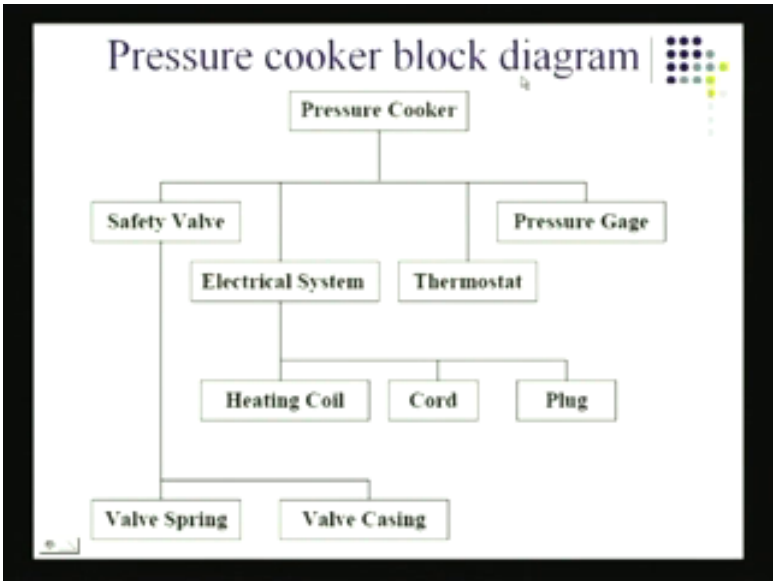

And for that, you again start with the block diagram, which is like the pressure cooker safety valve pressure gauge. These are subcomponents of it. It is a like your FTEA; this is very much like in FTEA. The electrical system could fail because of heating coil failure or chord failure plug failure there and the safety valve could fail because of valves spring not function properly or the valve casing not functioning properly.

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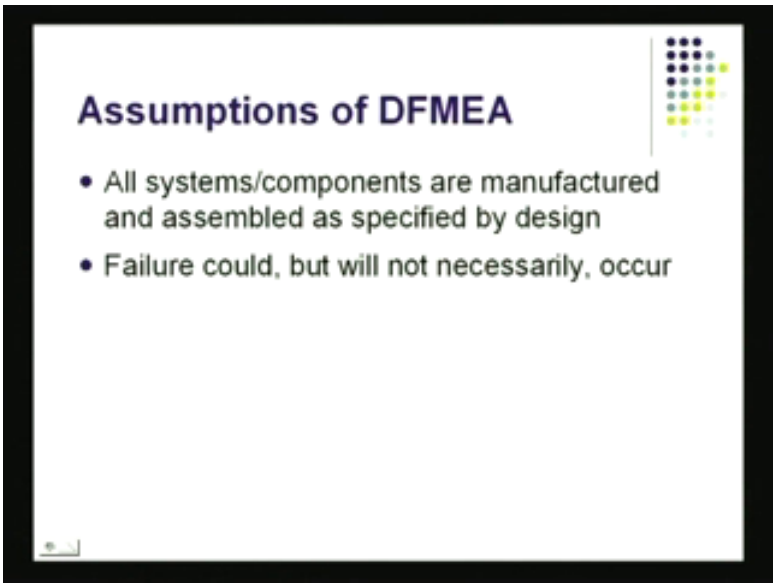

There are certain assumptions you make. You make sure that, the components that are used, those are functioning properly and that could lead that could lead to basically a problem in failure.

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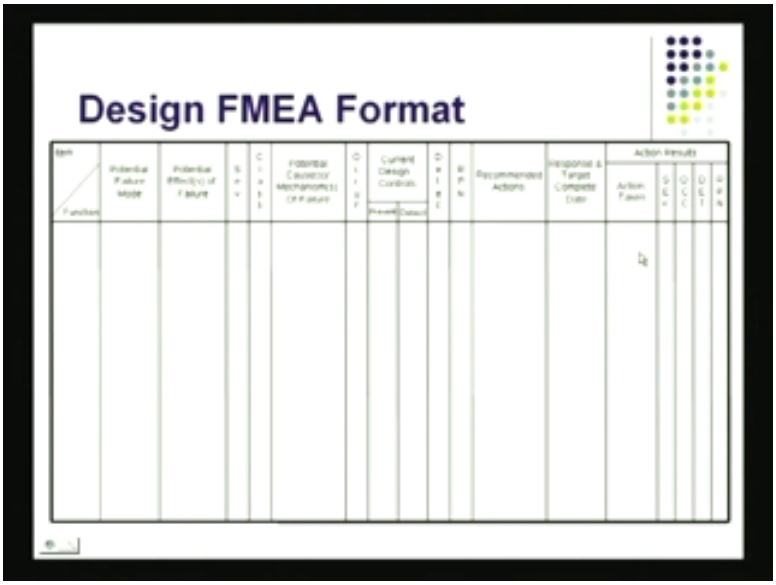

So, again let us get right back to our work sheet. Unless review what we have done so far. Some function is not being delivered, this is something we would like to able to check. We would like to able to prevent quotation causes for this. In what different ways could this function stop, so far them the engine does not work, and what different reasons what different reasons are there by the engine does not work. what is the effect of it? Well, you can see right away, what would the effect of the engine not starting there; what is the severity? What is the impact of it? And then of course, I have got some class and that will depend on this class there as I showed you earlier. Quotation causes or the mechanism the failure this would be like your mode, and you do your cause and effect diagram there occurs. This is again the probability of it and current design control to the to the to the do some prevention or with they do direct detection. And then detection rate this is something there will also got to figure out. So I have these three quantities severity occurrence, likelihood and detection capability. These lead to my RPN and the highest RPN would immediately get some attention there.

So, there will be some recommendation give to take care of this. Response and target completion there, these are there who is going to be taking that action there, and some other follow ups there are there.

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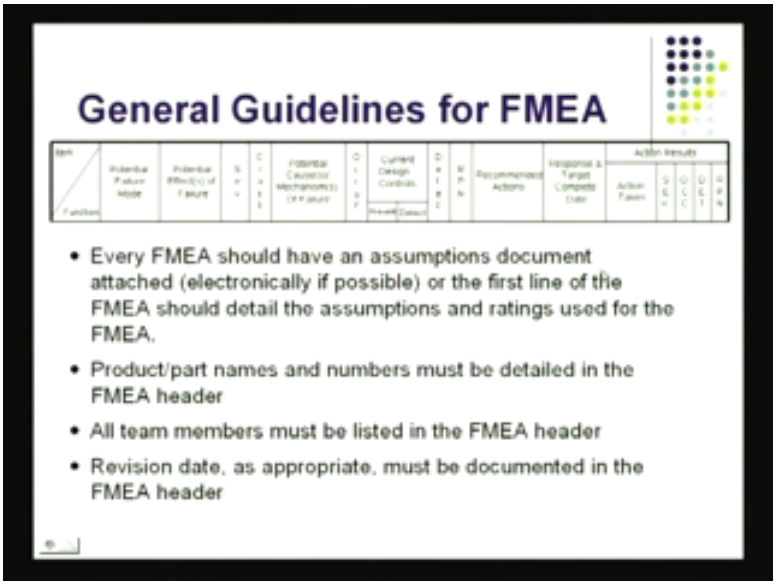

So, this is the work sheet that you should end up doing this. And I have these slides here, and these slides would be there, you can just flip through them after a certain point. They will tell, what are the functions expected; what are the how failure modes are going to take place; why are how are you going to discover the effects of that failure there; how are you going to find out severity; how are you going to find the class; how are you going to find the different ways; causes of failure; how are you going to find the frequency occurrence; how you are going to be find the current design controls if they are there; how are you going to look at the detection capability; how are you going to calculate the RPN, this is something you would like to able to do

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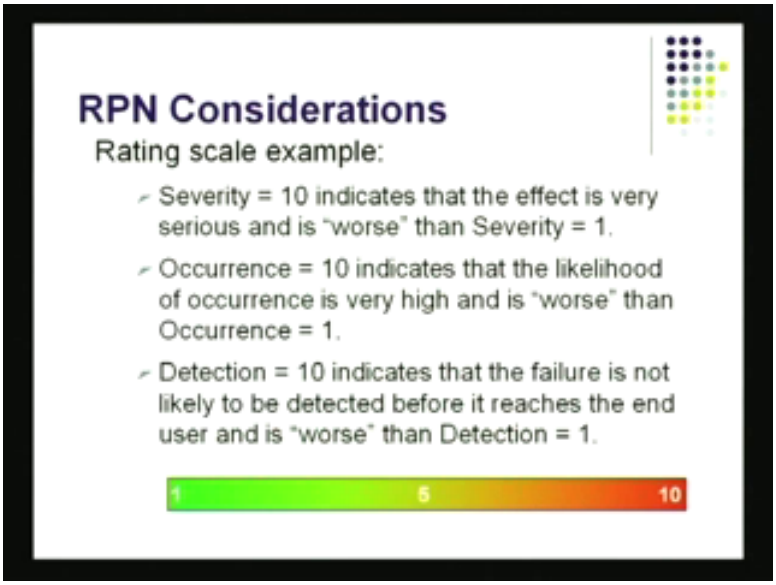

And of course, you want to be able to make sure that you high RPN items are there, all looked at before you go very further and recommended actions of course. This is

something, that you got be able to end with when you end up with your FMEA, you got some FMEA actions there.

Thank you very much, I really appreciate you are spending time in browsing through these videos there, and we are approaching fast the end of these forties session sequence of our lecture on six sigma. So, the course will be ending with two more lectures and there are two very interesting topic that are covering up, for you in the next two lectures. So see you soon thank you very much.