Chemical Process Safety
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Lecture 42
Event Tress
(Qualitative Risk Analysis)

Welcome to the new module pertaining to event trees that is the Quantitative Risk Analysis of any hazard or hazard process. Now it is in extremely important aspect for any kind of safety analysis because it relatively deals with the quantitative analysis that what are the probability and what are the different consequences for any kind of hazard that may happen during the process area. So let us have an overview about the event trees. In this particular module we will discuss about the various definitions related to event tree we will go for various steps or the procedures or the guidelines they are related to event tree analysis.

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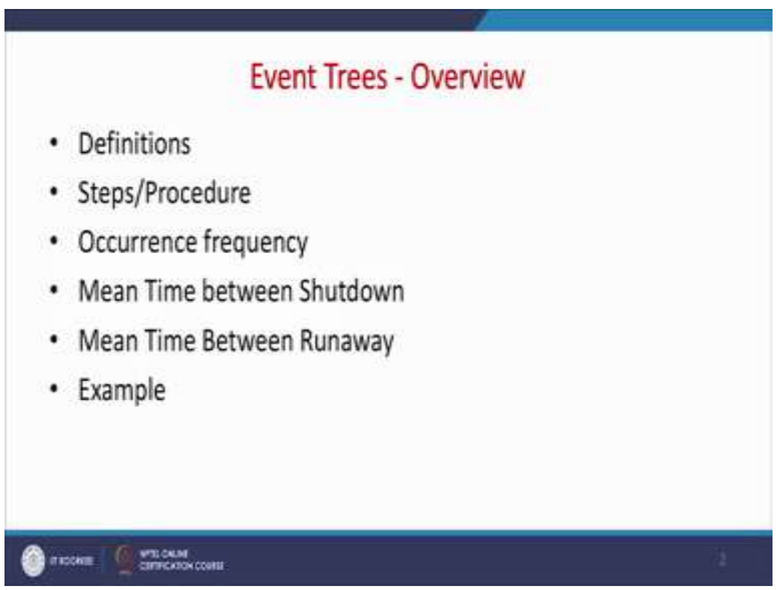

We will discuss about the occurrence frequency of nay incident then we will discuss the mean time between the shutdown mean time between the runaway with the help of certain examples. So let us have a look about the various definitions related to event tree.

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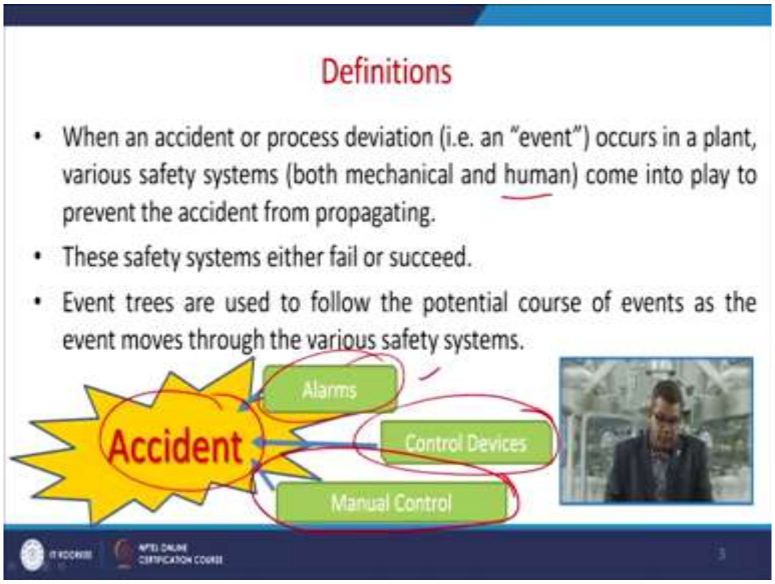

So when an accident or a process deviation that is an event sometimes it is referred as an event occurs in a plant the various safety systems both mechanical, human come into play to prevent the accident from propagating. Now, we must understand that whenever an there is a chance of an accident or accident takes place then there is some deviation of the process properties or the process scenarios because your process is customize for the safe operation with the help of certain safety devices etc. so you need to look into these deviations and these system these safety systems either fail or succeeds.

So whenever you have any kind of safety system then either it may fail or sometimes it may succeed with respect to its objective it is just like that you are having a pressure cooker that is the pressurized vessel it is equipped with two type of vents one is the safety wall another one is the safety vent. So frequently you may experience that steam is coming out or issuing from the safety vent and sometimes if anything fails or excessive build up then safety wall may rupture and by this way it can release excessive pressure whatever build in with respect to steam.

So in that particular case it succeeded but if it fails then there may be a chance that, that pressure vessel or a pressure cooker may collapse. So sometimes if it collapse then definitely it will attack to the weaker point. So that is why this safety system they have only two options either they fail or succeed. Now event trees they are used to follow the potential course of events as the event moves through various safety system.

So, let us have a look of this particular figure here you are having an accident now as a part of safety this particular system may have alarms so it may be actuated there may be certain control devices to prevent the accident so those control devices may fail or succeed then in case the of accident there may be certain manual involvement or the human factor which we have already discuss. So manual control may fail and sometimes the human error may involve so 1 or all 3 may contribute towards an accident.

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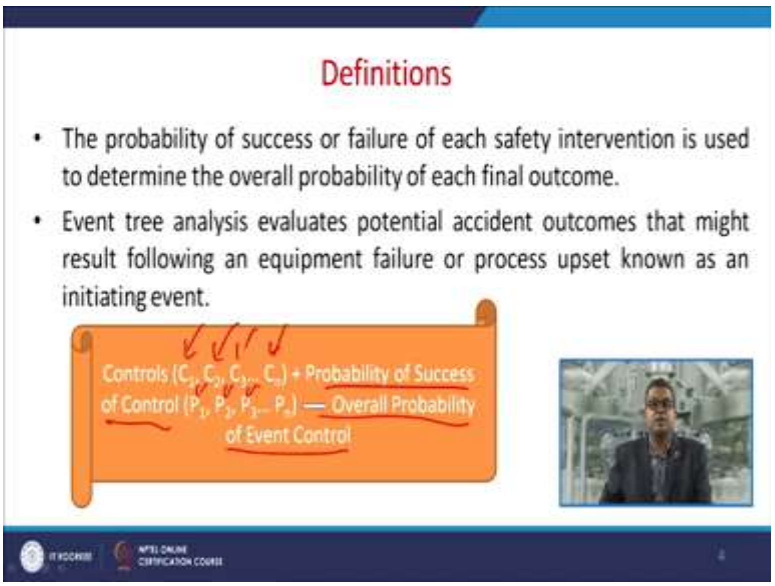

So the probability of success or failure of each safety intervention is used to determine the overall probability of each final outcome that is extremely important. So event tree analysis evaluates the potential accident outcome that might result following an equipment failure or a process upset known as initiating events.

So you must identify that initiating event. This may be in terms of this particular formula that is control you may have a different control the things C1, C2, C3 upto C n plus the probability of success of control that means you need to calculate the probability of each and every aspect that is P1, P2, P3 to P n that gives you the overall probability of that event control. So in case of accident you need to calculate the overall probability of those event and control.

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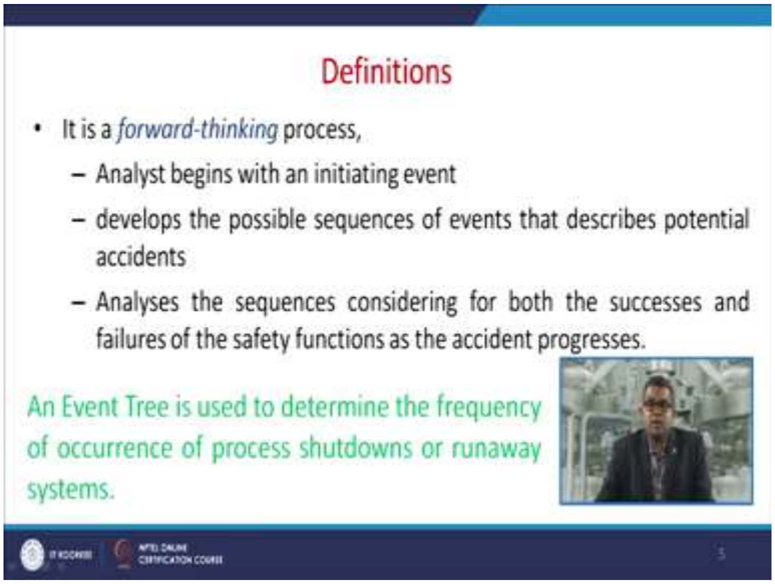

Now this analysis is a forward thinking process so analyst usually begins with an initiating event which we had discussed in the previous slide they developed the possible sequences of events that describes the potential accident the analysis the sequence considering for both successes and the failures of the safety function as the accident progresses.

Remember we sometimes in a common fashion we used to analyze the process with respect to the safety. We rarely or seldom we discuss about the failure of those safety devices. So event tree analysis or event tree the quantitative analysis argument all those aspects. So an event tree used to determine the frequency of occurrence of the process shutdowns or any kind of runaway systems.

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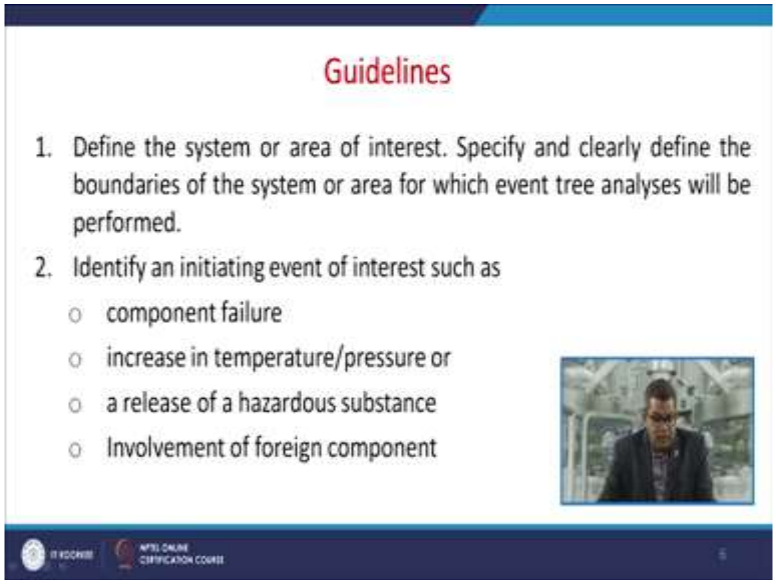

Now there are certain guidelines they are attributed to this event tree analysis now we have enlisted all those guidelines in various slides. Now first guidelines is the define the system or area of interest, so you need to specify mist have a clarity or a clearly define the boundaries of the system or area for which event tree analysis will be performed so you need to year mark that particular area then second aspect is that to identify an initiating event of interest like sometimes the component may failure component failure.

Sometimes it may happen that there is an increase in temperature or a pressure because various in past various accident took place just because of the temperature and pressure increment. There may be a chance of release of any kind of hazardous substance there may be a chance of involvement of nay foreign component that may be through raw material contamination or may be due to the process outcome may be a bi-product or side product or a base product.

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So based on this particular knowledge you conduct screening label risk assessment to identify the event of interest or categories of event that the analysis will address. So you must be very focused about it. Now this categories may include such things like as grounding, collision, fire, explosion or toxic releases. So we have enlisted all those things because they are the outcome like toxic release, fire grounding, explosions etc.

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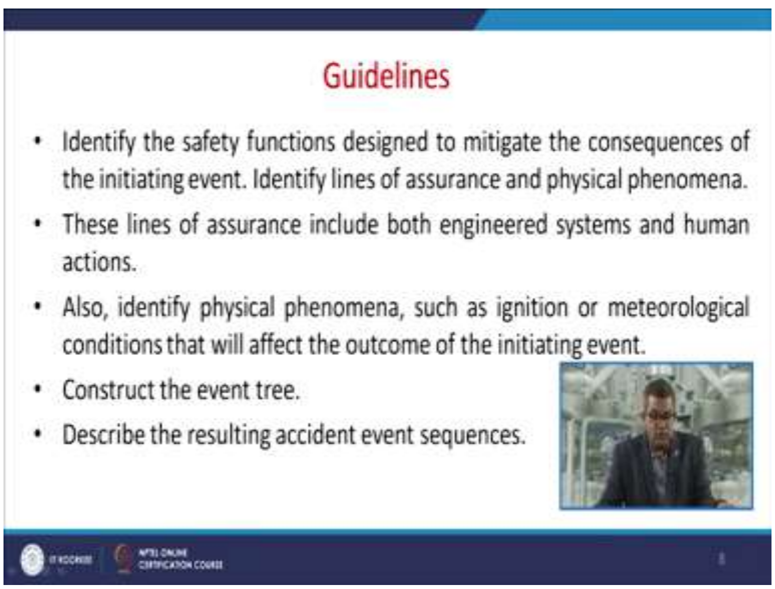

So on the basis of this particular aspect you identify the safety functions designed to mitigate the consequences of initiating event you need to identify the lines of assurance and a physical phenomena. Now this lines of assurance include both engineered system and the human attention because you cannot overlook the importance of this human actions also identify the physical phenomena like ignition some sort of meteorological conditions that will affect the outcome of initiating event in past there are several incidents like if they were the meteorological conditions plays a vital role sometimes the atmosphere is heavy sometimes the humidity is on the higher side, sometimes the wind direction may play a vital role.

Suppose there is a toxic release then if the wind direction is towards the populated area then the consequences would be on the higher side compared to the wind direction towards the low populated area or rare area. So you need to identify all those physical phenomena then you need to construct the event tree and on the basis of this you describe the resulting accident event sequences.

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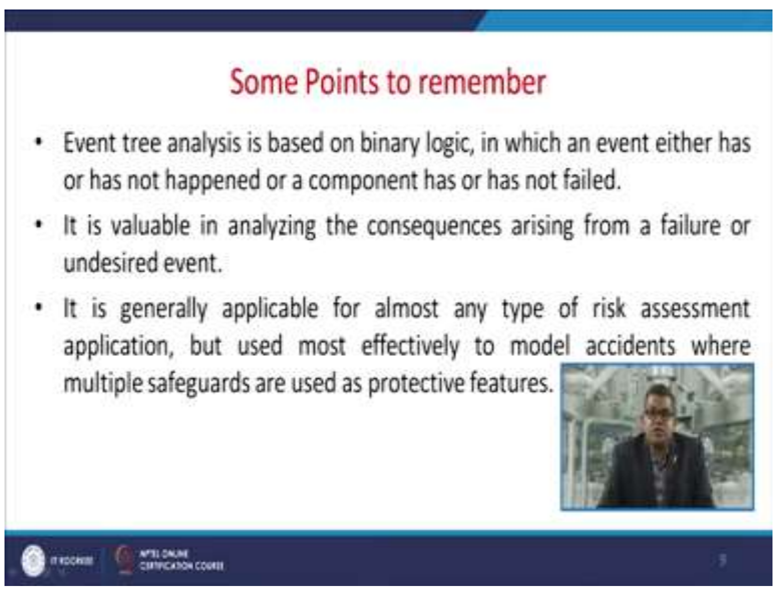

So there are certain points you need to remember and those points are that event tree analysis is based on binary logic in which an event either has or has not happened or compared has or has not failed. So there are only two option either this work or will not work. So it is a valuable in analyzing the consequences arising from a failure or undesired event. It is generally applicable for almost any type of risk assessment applications but used most effectively in model accident where the multiple safe guards are used as a protective feature.

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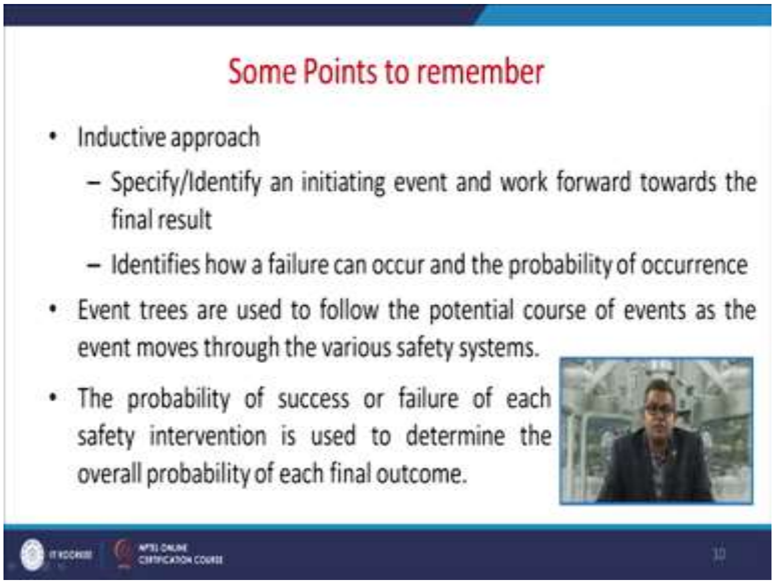

Now there is one approach called inductive approach in this approach you need to specify or identify an initiating event and work forward towards the final result. This identifies how a failure can occur and what is the probability of the occurrence of that particular failure?

So this particular aspect is important while calculating the consequences. So event trees they are used to follow the potential course of event as the event moves through the various safety systems. The probability of success or failure of each safety intervention is used to determine the overall probability of each final outcome.

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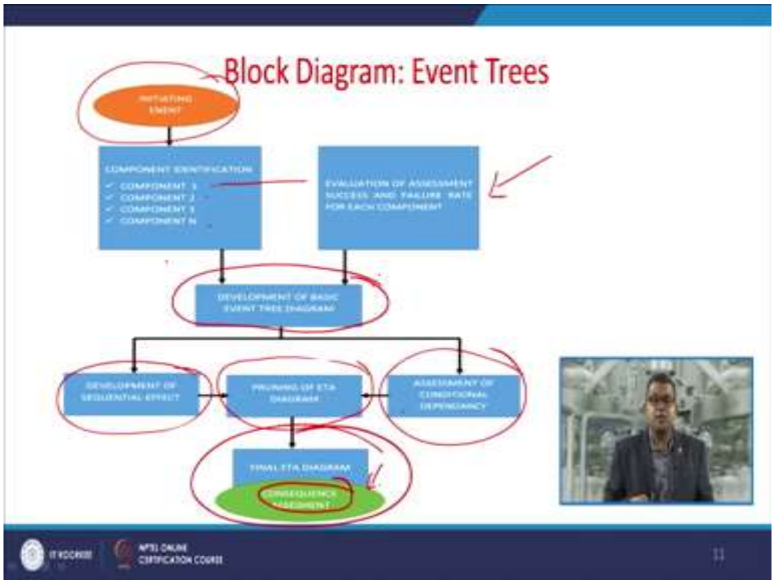

Now let us have a look of this block diagram related to the event tree, you are having some initiating events may be based on different type of component identification component 1, 2, 3 upto component n then simultaneously you are evaluation of assessment success and failure rate for each component so based on this particular aspect you are analyzing this failure rate of each component then based on this two important information there is a development of basic event tree diagram.

Now it can be divided into three different aspect one is that the development of sequential effect this may lead to the pruning of event tree analysis diagram and second thing is that assessment of conditional dependency this is again attributed to the pruning of the event tree diagram. So based on this particular aspect you can construct the final event tree analysis diagram and on the basis of this diagram you can go ahead with the consequence assessment.

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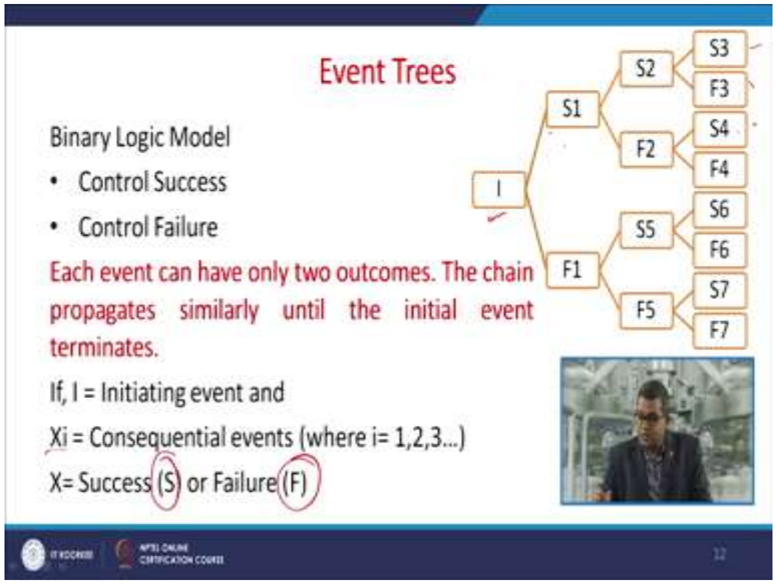

So let us have a look about the binary logic model based on two things one is the control success another one is the control failure. So each event can have only (one) two outcome this two that is the success or failure the chain propagates similarly until the initial event terminates. So if let us have look that if I is the initiating event and let us see that xi is the consequential events where I is equal to 1, 2, 3 and x is the success that is s and failure F. So this is the initiating event maybe success failure then again this success may be attributed to S2 F2 based on all kind of aspects and everywhere you can design this two steps success, failure etc.

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So the first step that is the identification of initiating event like this then the second step that identification of safety function designed to deal with the initiating event this one then you go for construction of event tree that is step 3then you classify the outcome that is you describe the resulting event sequences and next step is to estimate the conditional probability of each branch here you can have the conditional probability of each branch then you go for quantification of outcomes in the next step and based on all this aspect you go for evaluation.

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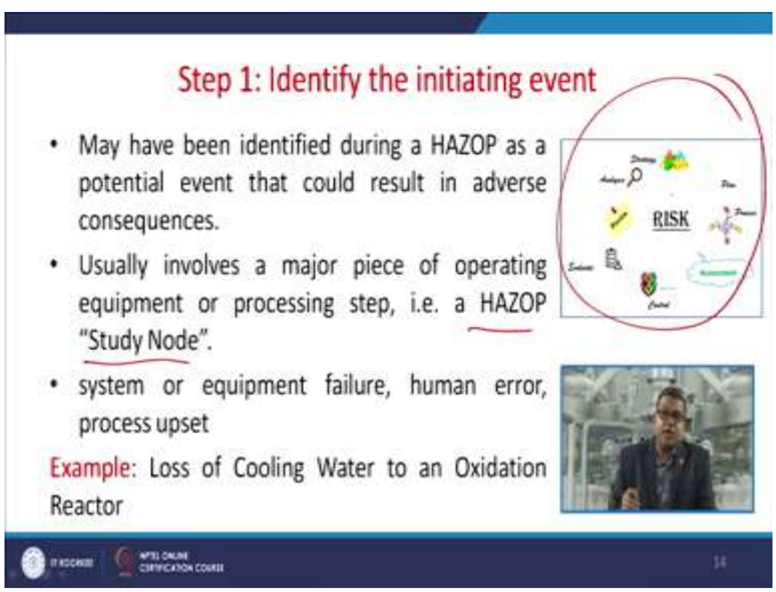

So the first step that is the identification of initiating event this may be identified during the HAZOP as a potential event that could result in the adverse consequences so usually this involves a major piece of operating equipment or processing step that is HAZOP or sometimes Study Node. Now, the system or equipment failure human error or the process upset so one example is that loss of cooling water to an oxidation reactor. So the you may have a different type of aspect in the initiating event like strategy, risk different type of control methodology you may have the proper information related to that particular industry or a process and these are the supporting events for to identify the initiating event.

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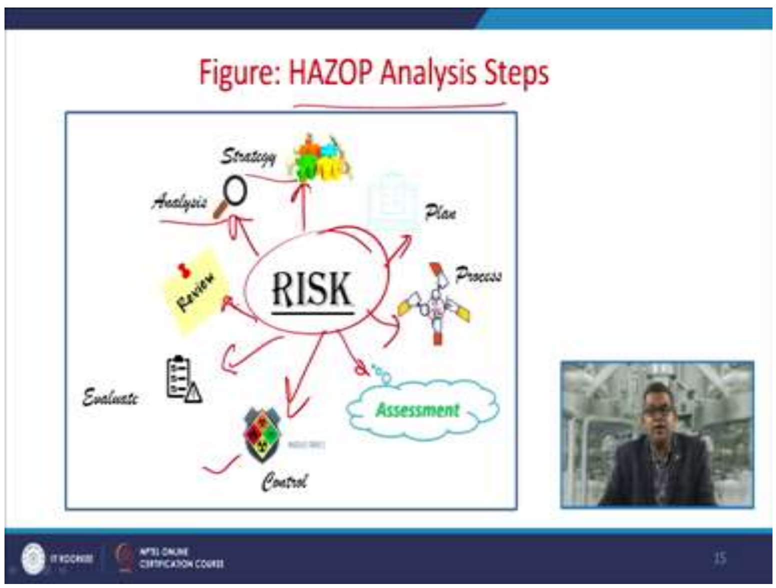

So you analyze these aspect with the help of HAZOP analysis step like you must have a proper strategy and go for analysis if this is the risk then you must have a plan then the process all information related to the process must be available based on the process you go for the assessment, what are the controlled methodology based on the information available to with the various resources then you need to evaluate perform the review go for the analysis and perform the strategy so all this aspects are sometimes (())(15:03) if you perform this kind of HAZOP analysis.

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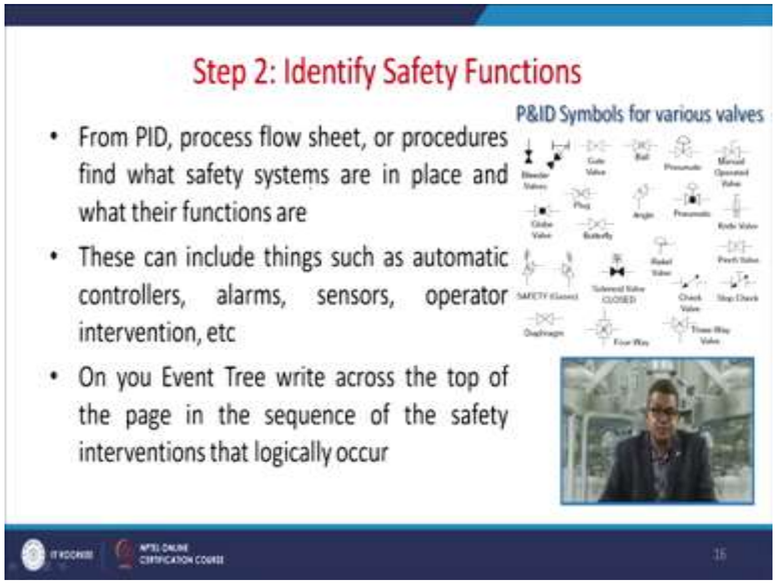

Then you identify the safety functions so from PID process flow sheet or a procedure find what is safety systems are in place and what their functions are? So here we have enlisted different P&ID symbols for various valves like Bleeder valve, Gate valve, Ball etc. Now this can include things such as automatic controllers, alarms, sensors, operator interventions etc. So on you Event tree write across the top of the page in the sequence of safety interventions that logically occurs.

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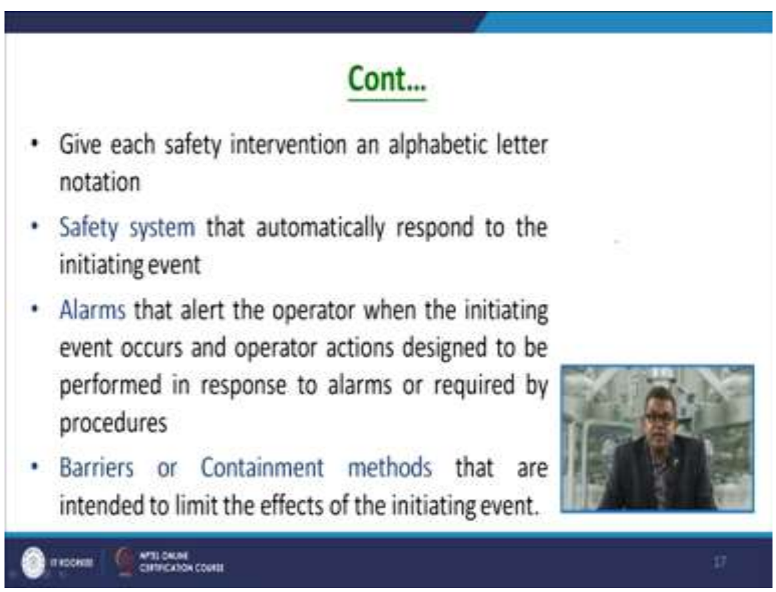

So you give each safety interventions an alphabetic letter notation then the safety system that automatically respond to the initiating event. The alarm usually sometimes you use the term alarm usually alarm that alert the operator when the initiating event occurs and operator action designed to be performed in response to alarms are required by the procedures. So there are several barriers or containment methods etc. Now this are the intended to limit the effect of that particular initiating event. So this is the inherent property of that event.

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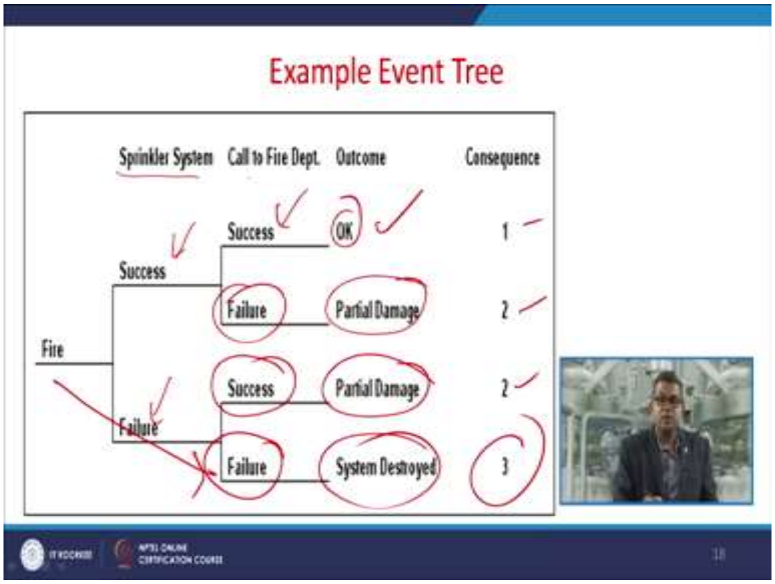

So this is the example of event tree now we are having the sprinkler system there is a methodology called Call to Fire Department, Outcome and a Consequences. You may have a fire there may be chance that sprinkler system may succeed or it may be chance of a failure. Now if it succeeds then this is subdivided into two things success or a failure.

Now if it success then it is ok no problem but if it fails then there may b chance of partial damage. So this is the consequence 2 and this is 1. Now in case of failure then the failure methodology (fails) succeed then there may be a chance of a partial damage the consequence 2. Now if it fail then there may be chance of system destroy so the consequence is 3 so this is the outcome this is the methodology and this is the process of initiating step.

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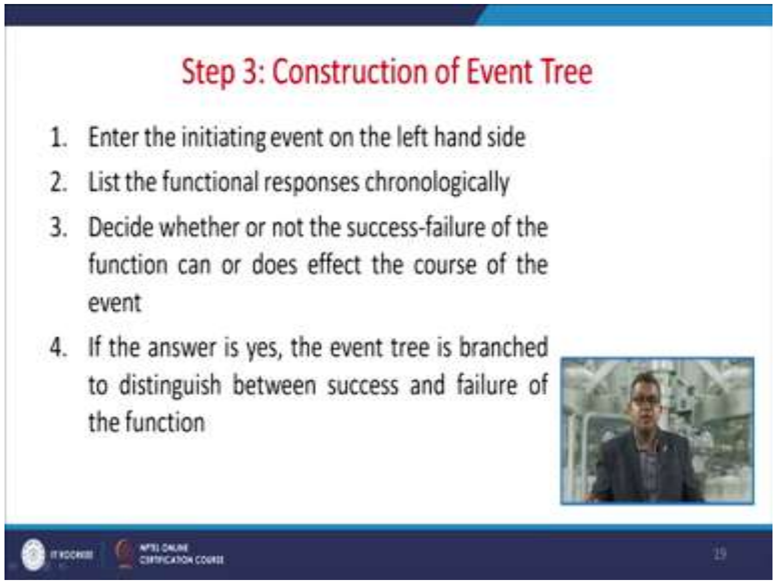

Now step 3 is the construction of event tree so you enter the initiating event on the left hand side like this then list to the functional responses chronologically here you have enlisted all the functional responses then decide whether or not the success failure of the function can or does effect the course of the event here which we have enlisted. Now if answer is yes the event tress branched to distinguish between the success and failure of the function here we have the branched in success and failure in both the aspect.

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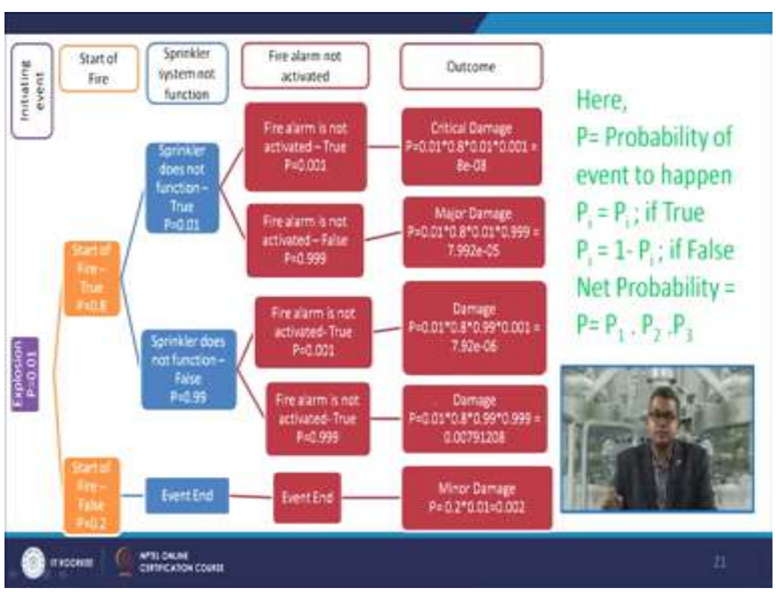

The horizontal lines they are drawn between the function that applies here you have applied the horizontal lines. Vertical lines are drawn with each safety functions that applies like success upward, failure downward and no effect there would be no branch at all. Now indicate the result of event that is circle you may indicate with the acceptable result, the cross circle that is unacceptable result like this.

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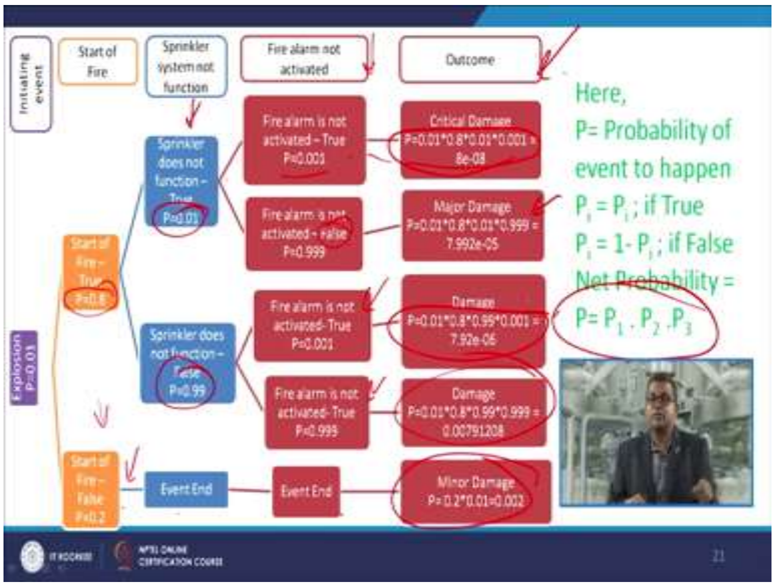

So here again one example is given that is explosion, the P is equal to 0.1 that is the probability of event to happen now in case of explosion the start of fire that is true because the probability is 0.8 and start of fire that is false that means there is a failure, the probability is 0.2 then start of fire that means the success then the sprinkler system not functioning that is sprinkler does not function the probability is this one then sprinkler does not function then this one then the fire alarm is not activated, fire alarm is not activated that is false, success failure may be activated may not be activated, then if it is not activated succeed then the critical damage you analyze through this one that is the outcome.

Similarly, if it is not activated that is the failure then the major damage is like this, similarly sprinkler does not function the fire alarm is not activated this is the interlinked things so that is the success then the damage is represented by this one. The fire alarm is not activated then the damage is given by this one. Now this gives you the event end that is (())(20:28) minor damage.

So here the Pi at is equal to P i if true then Pi is equal to 1 minus p if the false so net probability is given by this function.

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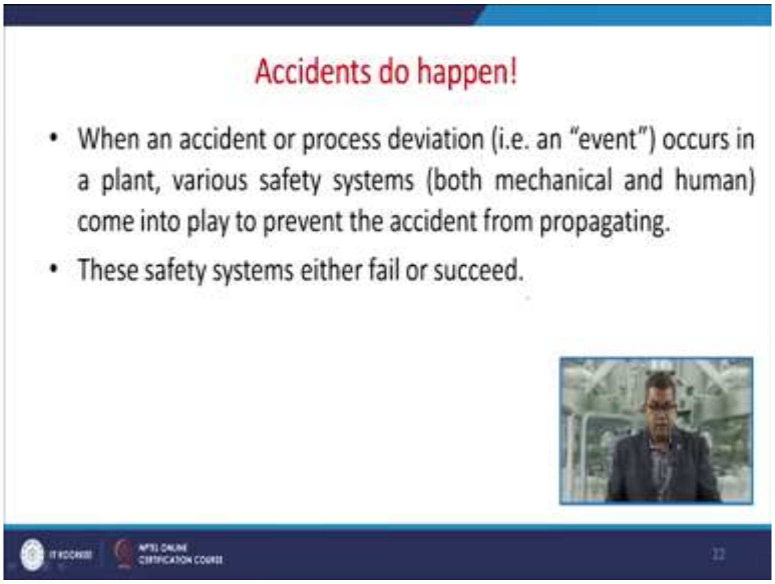

Now accidents they do happen so when accident or process deviation that is an event occurs in a plant various safety system both mechanical and human come into play to prevent the accident from propagation. Now these safety system either fail or succeed.

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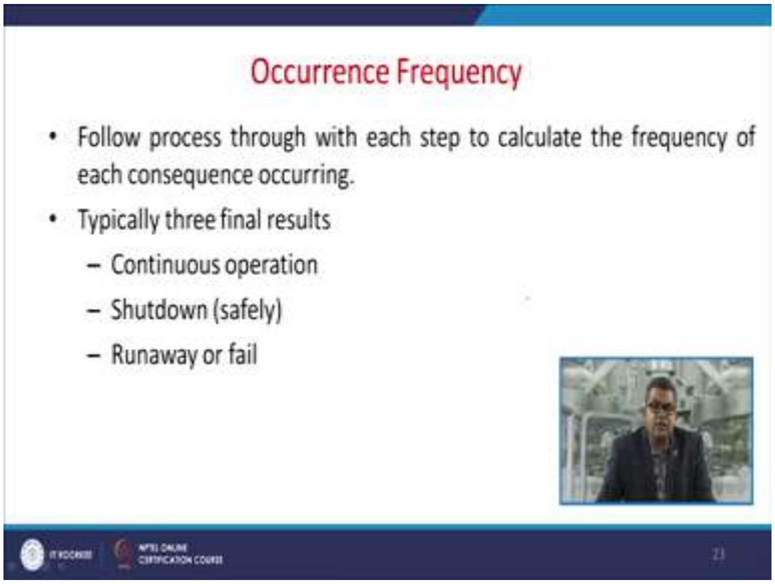

So we must look into the occurrence frequency so the follow the process through which each step to calculate the frequency of each consequence occurring now typically there are three final results maybe in terms of continuous operation, may be the safe shut down or may be the run away or a failure. So you have to look into three different results.

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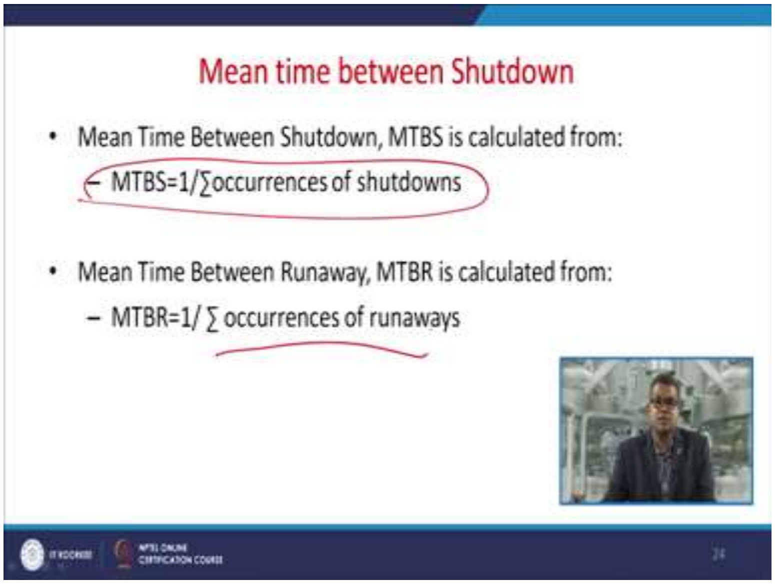

Now there is a concept of Mean Time between the shutdown so you need to evaluate this one the mean time between the shutdown MTBS is calculated from this formula MTBS is equal to 1 upon summation occurrence of all kind of shutdowns. So the Mean Time Between the Runaway reactions MTBR is calculated by this one MTBR is equal to 1 upon summation of occurrence of various Runaways.

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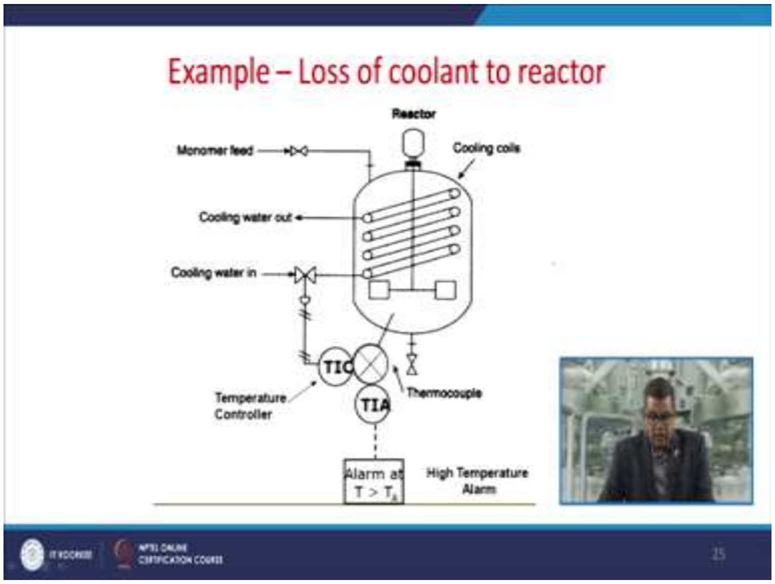

Now let us have another example of loss of coolant to reactor, sometimes it is a usual practice and it do occurs when we are having one any exothermic reaction or exothermic process within the systems so you may have to go because of the catalytic requirement or because may be because of the process requirement sometimes you may need to introduce the coolant. So that the reaction temperature maybe at the appropriate level.

Now here this is a polymerization reaction here you are having a monomer feed this is the cooling water coil here you are supplying the counter current cooling water and here the cooling water which is at elevated temperatures coming out you are having the temperature controller usually sense and usually actuates when there is a need of cooling.

So it may happen when you are not having the continuous cooling type of system so if it is if the system reaction temperature goes beyond the acceptable limit then this temperature controller activates and its sense to the cooling water so that the adequate supply of cooling water may inside the thing. Now this temperature controller is usually affected or usually gets sensed by this thermocouple.

Now here there is hig temperature alarm sometimes if it fails then this alarm will actuate and it sensed or it gives an indication to the operator in question so that the remedial measure can be taken for to avoid any kind of process damage and sometimes it may happen because sometimes this thermocouple may have a faulty this temperature controller may have the faulty things.

So if there is a reason the temperature rise in the temperature then this alarm will come into the picture. So this if you see this particular figure there are three different safety devices one is the temperature controller another one is this thermocouple another one is the alarm. Apart from this you are having the cooling water supply and this cooling water supply is usually supported by this temperature controllers sensors.

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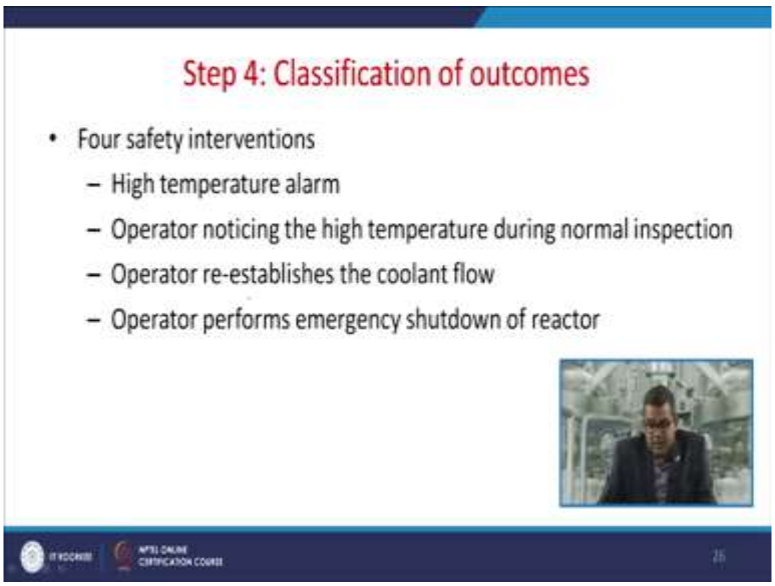

Our next step is that you need to classify the outcomes, now there are four safety interventions one is that high temperature alarm, sometimes the operator notice in the high temperature during the normal inspection when operator reestablishes the coolant flow sometimes because of the failure of this things so he actually reestablish the cooling flow and then operator performs the emergency shutdown of reactor.

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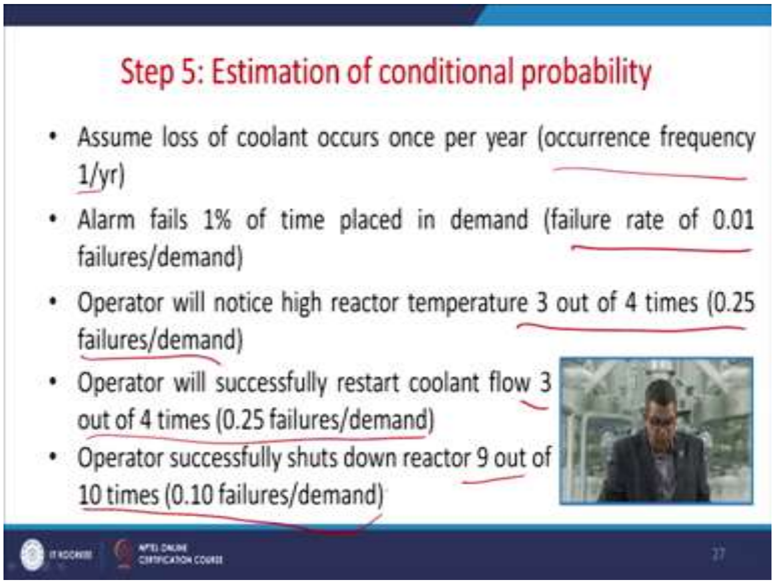

Then you may go ahead with the estimation of the conditional probability, now assume the loss of coolant occurs once per year that is the occurrence frequency is 1 is every year. Now alarm fails say 1% of time placed in demand that is the failure rate of 0.1 failures per demand then operator will notice how reactor temperature 3 out of 4 times that is 0.25 failures per demand. The operator will successfully restart the coolant flow 3 out of 4 times that is 0.25 failures per demand then operator successfully shutdown reactor 9 out of 10 times so this are the probabilities so 0.1 failures per demand.

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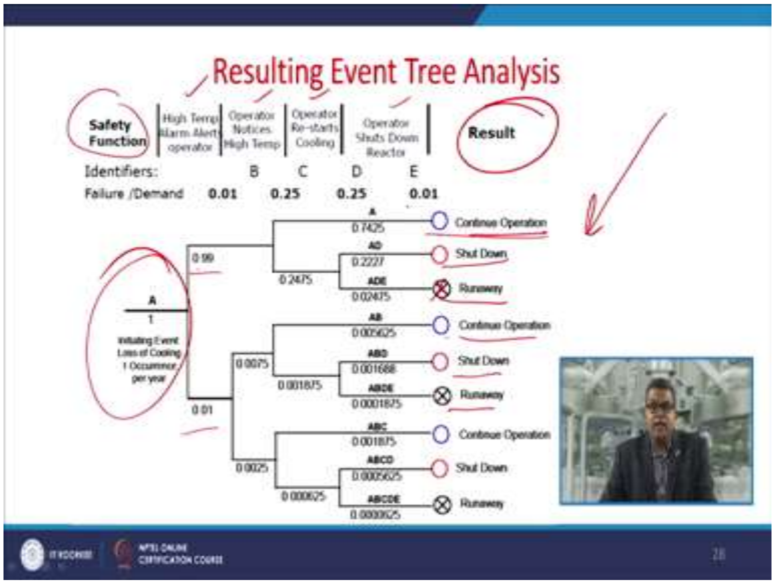

So you may construct this the entire event with the help of this result event tree analysis, you are having the safety functions like high temperature alarm, operator notices the high temperature operator restarts the cooling and operator shutdown the reaction. So here you may notice that initiating event that is the loss of cooling 1 occurrence per year we have already may noticed then based on this analysis 0.99 and 0.1 then go ahead the success failure then continue you go for this continue operation then there may be a chance of shutdown runway reaction then the circle is crossed. Now if it is there then the continuous operation shutdown runway reaction so you may construct by this way in terms of result you may construct this event tree protocol and then you perform the event tree analysis.

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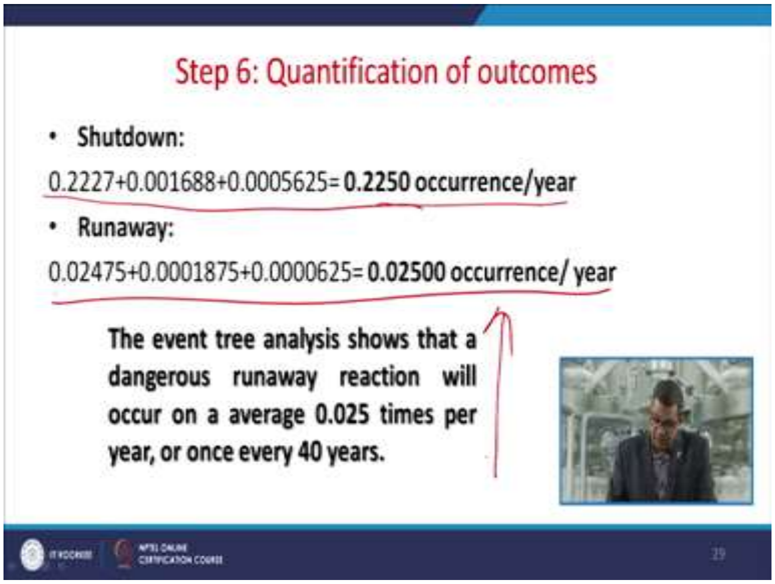

Then we go for the quantification of outcome recall the previous formula if we are having the shutdown then we have to sum up this thing summation that is 0.2250 occurrence per year based on this particular protocols and if there is a runaway you can calculate this one, this one etc. So we are having the 3 conditions of runaway, 1, 2 and 3 so after summing up it comes out to be 0.2500 occurrence per year. Now the event tree analysis show that dangerous runaway reaction will occur on an average of 0.25 times per year or once in every 40 years this is very critical analysis.

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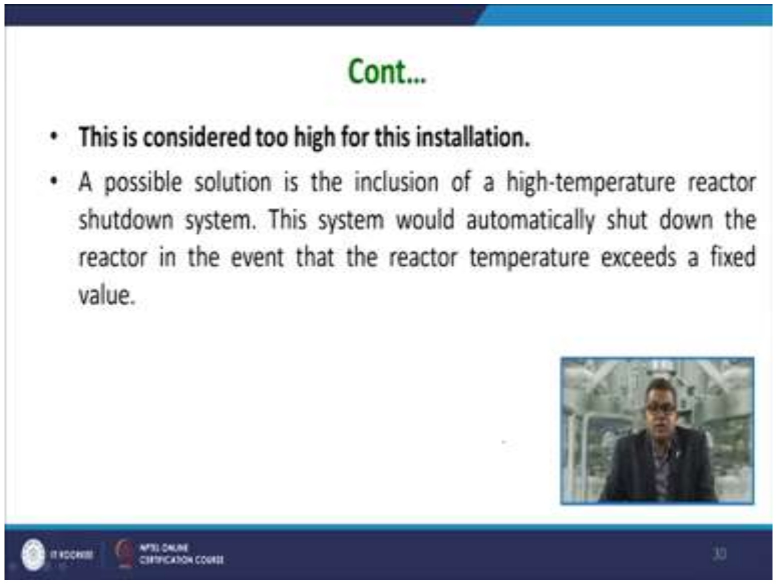

So this is considered too high for this type of installation. Now possible solution of this inclusion of high temperature reactor shutdown system this system would automatically shutdown the reactor in the event that the reactor temperature exceeds a fixed value.

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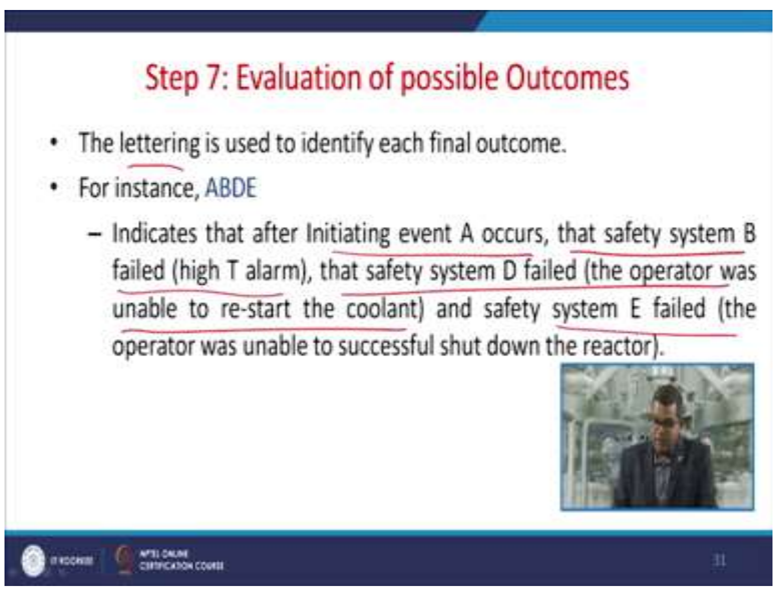

Now the next step is the evaluation of a possible outcome so the lettering is used to identify the each final outcome, for instance ABDE in this the indicates that after initiating event A occurs the safety system B failed that is high temperature alarm the safety system B failed the operator was unable to restart the coolant and the safety system E failed that the operator was unable to successfully shutdown the reactor that is the extreme condition.

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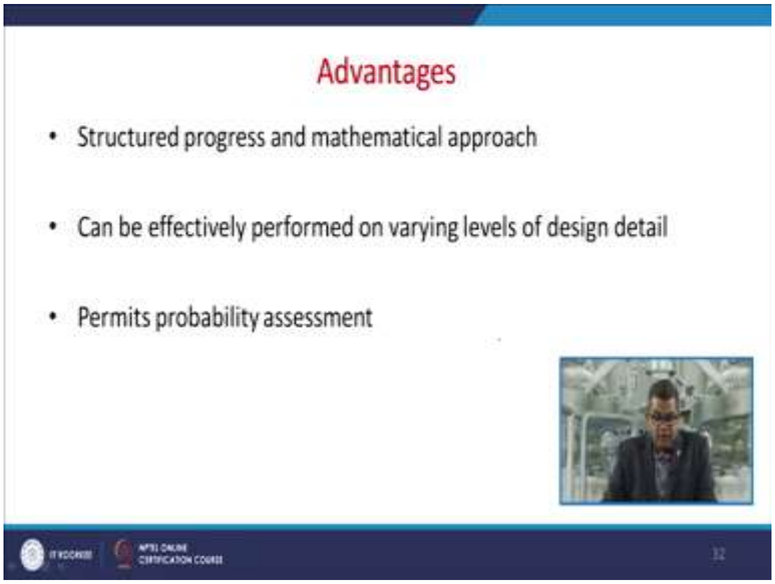

So the advantage let us have a discussion about the advantage. They are the structured progress and mathematical approach it gives the quantitative analysis this can be effectively performed on varying levels of design details may permit the probability assessment.

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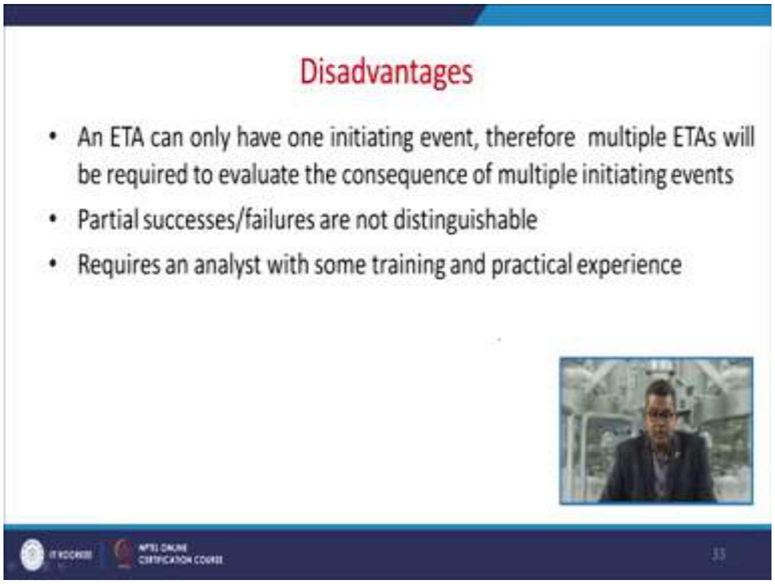

Once we are having the advantages then obviously it comes with certain disadvantages so the event tree analysis can only have one initiating event therefore multiple ETAs will be required to evaluate the consequence of multiple initiating event. So it becomes extremely (())(29:19) the partial success failure are not distinguishable this is I see as disadvantage. We require some analyst with some training and the practical experience.

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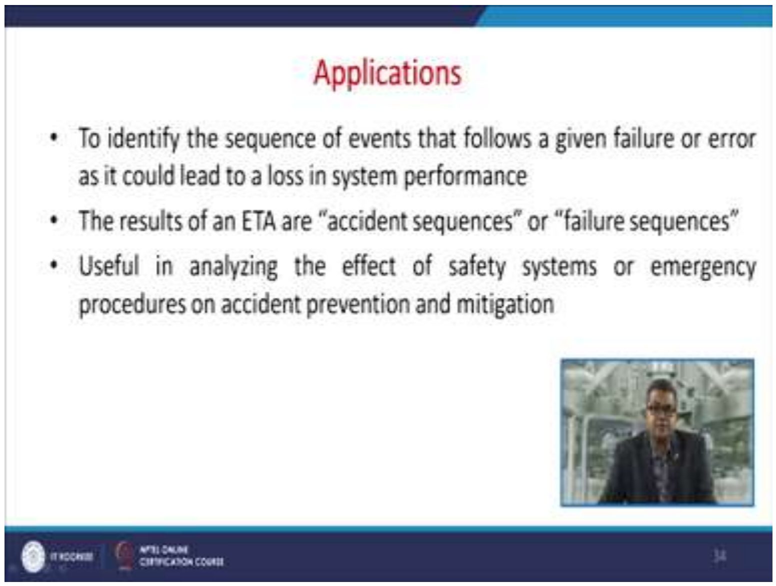

Now let us talk about the applications of this ETA, to identify the sequence of event that follows a given failure or error as it could lead to a loss in system performance the result of an event tree analysis are accident sequences or failure sequences they are useful in analyzing the effect of safety system or emergency protocols or procedure on accident prevention and mitigation.

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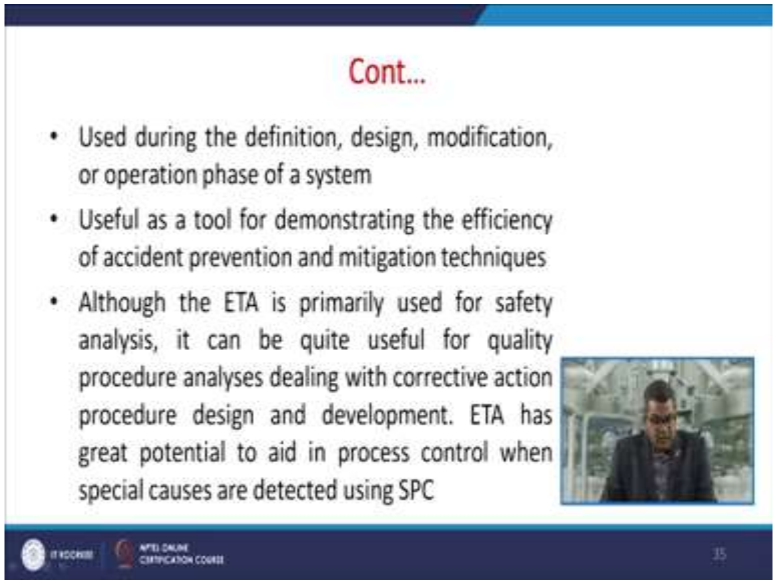

They are used to during the definition, design, modification or operation phase of a system so they are having the very wide spectrum. Now used as a tool for demonstrating the efficiency of accident prevention and mitigation techniques. Now although this event tree analysis is priory used for the safety analysis it can be quite useful for quality procedure analysis dealing with the correct action procedure design and development. So this analysis has a great potential to add in process control special cases are detected using this SPC.

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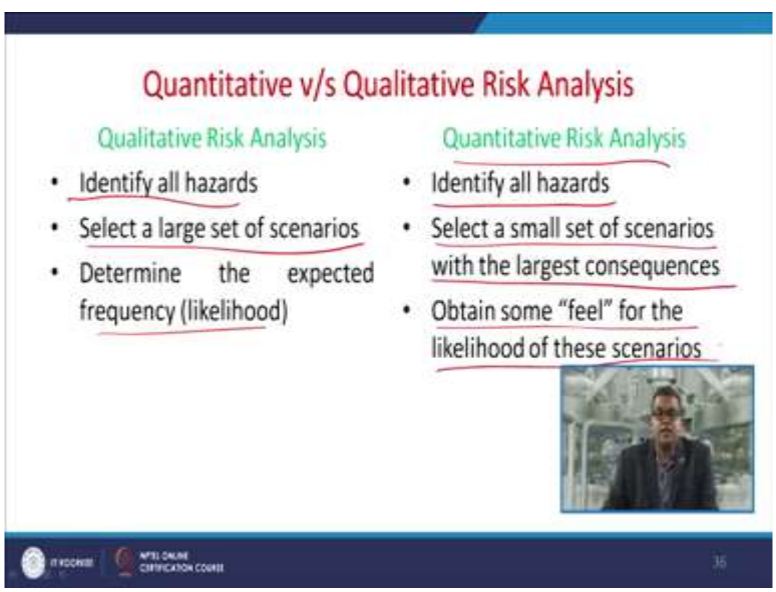

So let us have a look about the quantitative and qualitative analysis a comparison chart. Now the qualitative risk analysis is they identify all hazards the quantitative risk analysis identify all hazards so both are equal in this case. Now here in the qualitative risk analysis they select a large set of scenarios in the quantitative risk analysis they select a small set of scenarios which with the largest consequences so you need to find out all this scenarios. Now in the qualitative and risk analysis they determine the expected frequency that is the likelihood whereas the quantitative risk analysis obtain some feel for the likelihood of these scenarios.

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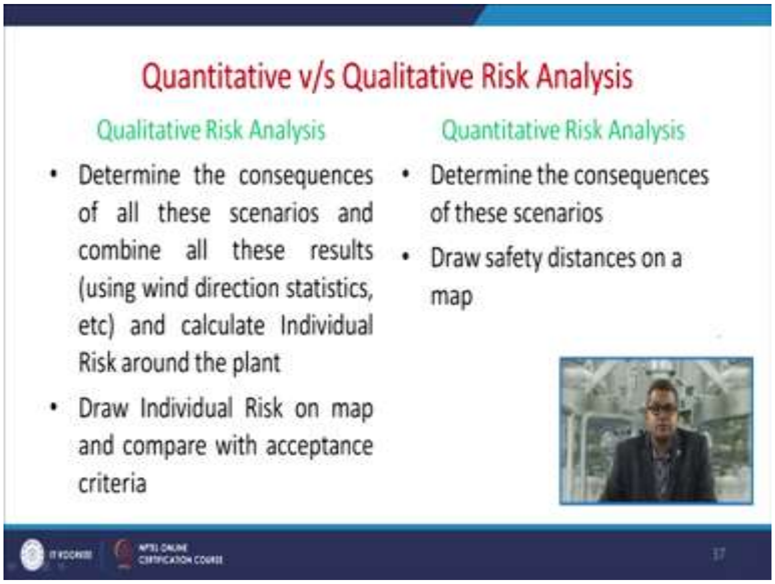

The qualitative risk analysis they determine the consequence of all these scenarios and combine all this result using wind directions like wind direction statistics etc and they calculate the individual risk around the plant where is the quantitative risk analysis they determine the consequences of this scenarios. Now in qualitative risk analysis you need to draw the individual risk on map and compare with the acceptance criteria here in the quantitative risk analysis you need to draw safety distances and a particular map.

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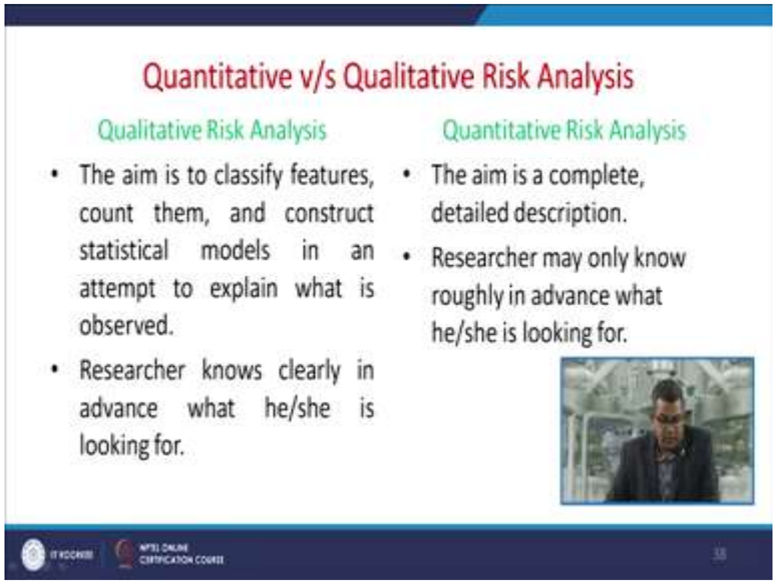

Now in qualitative risk analysis the aim is to classify the features, count them and construct statistical models in an attempt to explain what is observed. Whereas in quantitative risk analysis the aim is to complete detailed description. In qualitative risk analysis the researcher knows clearly in advance that what he or she is looking for whereas in quantitative risk analysis the researcher may only know roughly in advance what he or she is looking for.

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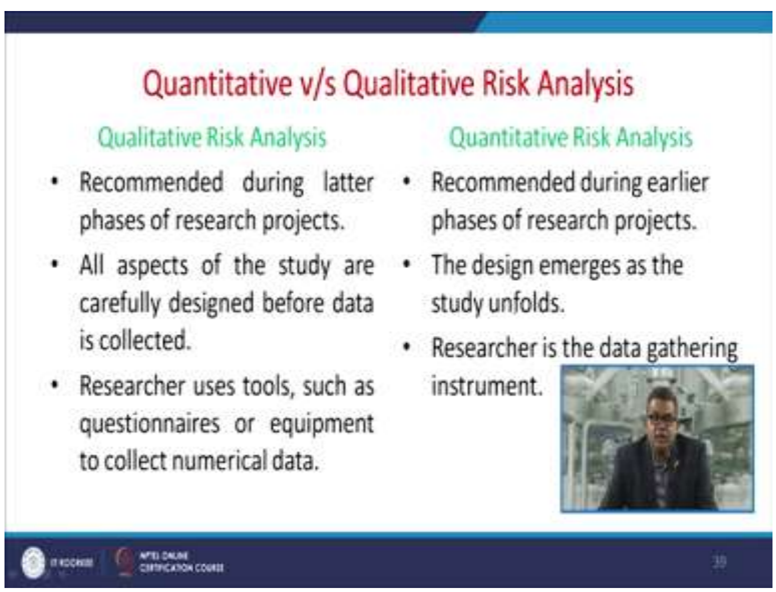

The qualitative risk analysis is recommended during the later phase of any kind of research project whereas the quantitative risk analysis recommended during earlier phase of a particular project. In qualitative risk analysis the all aspect of study are carefully designed before data is collected. In quantitative risk analysis the design emerges as the study unfolds. So in qualitative risk analysis the researcher uses tool such as questionnaire or equipment to collect the numerical data whereas in quantitative analysis the researcher is the data gathering instrument. So this is again very crucial.

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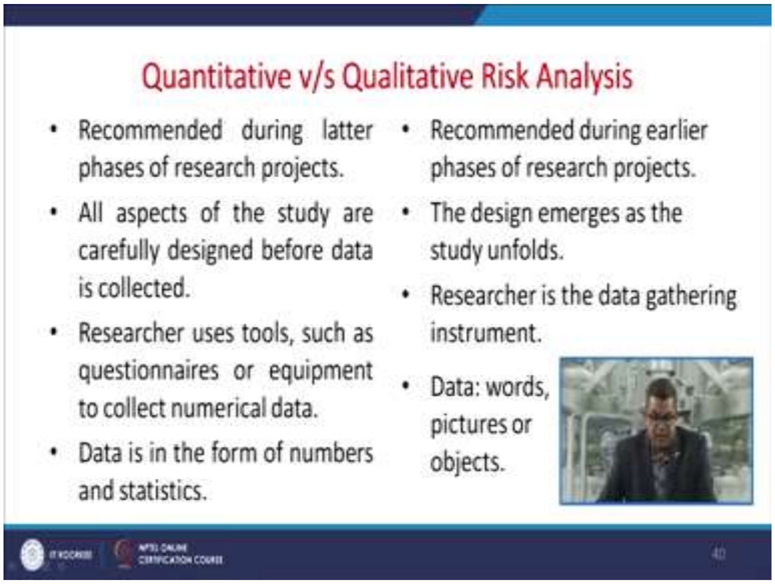

Now the (quantitative) qualitative risk analysis is recommended during the later phase of any kind of research project and this quantitative risk analysis is recommended during the earlier phase of risk research project. So in all aspect of study they are carefully designed before data is collected in qualitative one whereas the design emerges as the study unfolds in the qualitative analysis. So in qualitative analysis data is usually in the form of numbers and statistics whereas in quantitative analysis the data are in terms of words, pictures or various objects.

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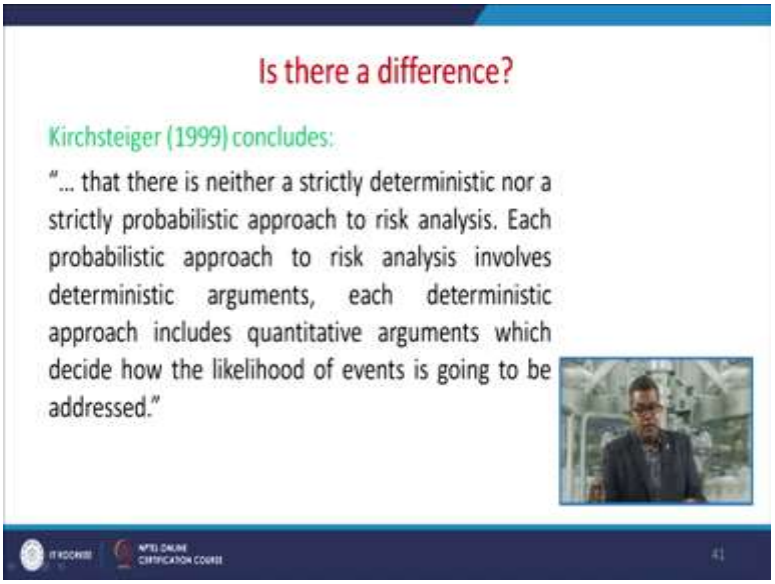

Now question being asked that is there any difference so one scientist is that there is neither strictly deterministic nor strictly probabilistic approach to risk analysis each probabilistic approach to risk analysis involves deterministic argument such as deterministic approach includes quantitative argument which decide how the likelihood of event is going to be addressed.

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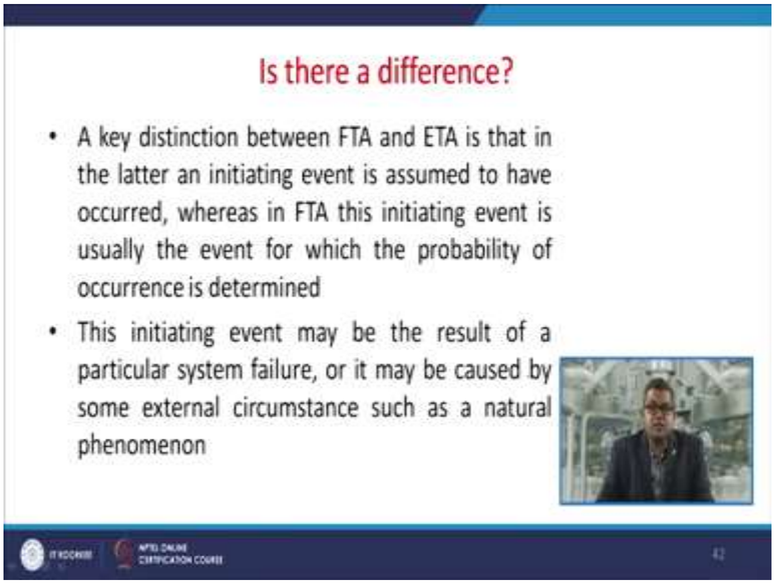

A key distinction between the fault tree analysis and event tree analysis. Fault tree we are going to discuss in next in other module is that in the later that is in event tree analysis an initiating event is assumed to have occurred whereas is in fault tree analysis this initiating event is usually the event for which the probability of occurrences s determined. So the initiating event maybe the result of a particular system failure or it maybe caused by some external circumstances such as natural phenomena etc. so in this particular module we have discussed about the event tree analysis, what are the different guidelines associate for event tree analysis, what is the impact of this event tree analysis in terms of qualitative and quantitative analysis in the process industry.

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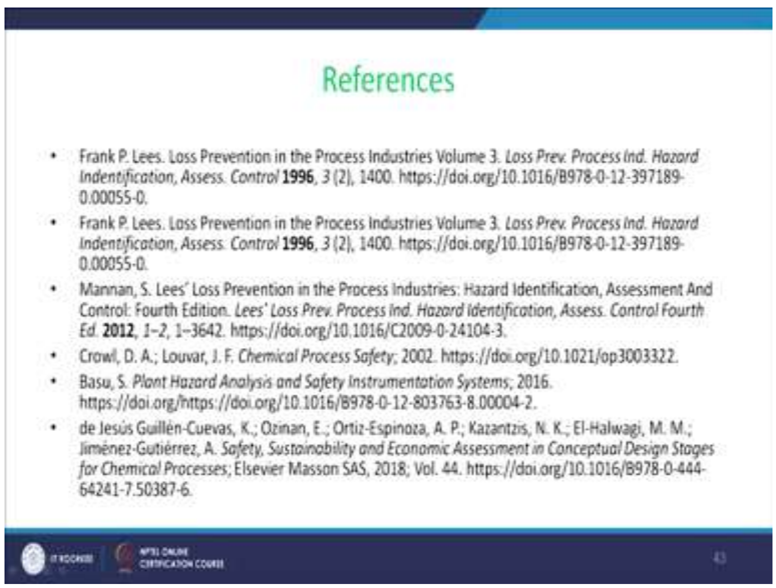

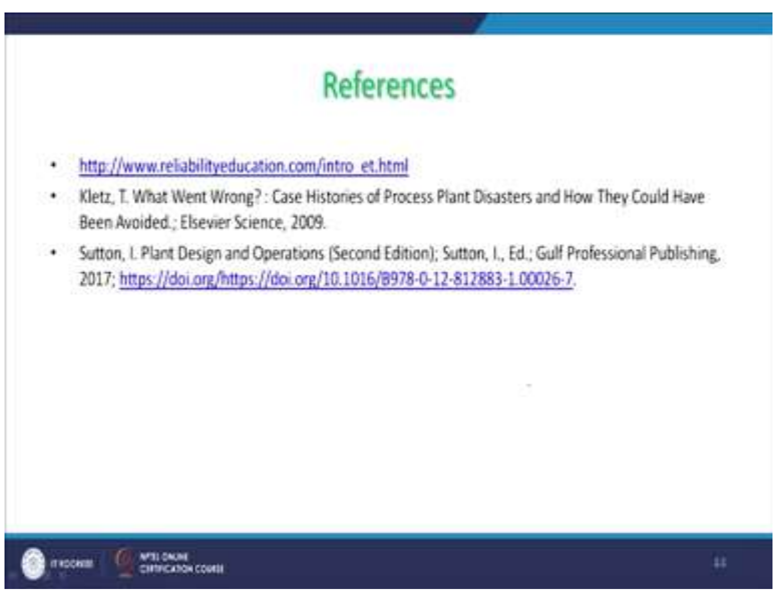

So you may for further reading you may have a look of the these references which are enlisted over here thank you very much.