NPTEL

NPTEL ONLINE CERTIFICATION COURSE

Health, Safety & Environmental Management in Offshore and Petroleum engineering (HSE)

Module 2:
Accident modeling, Risk assessment & Management
Lecture 10: Event Tree and Fault Tree analysis

Friends in today's lecture which is lecture number 10 we will focus on event tree and fault tree analysis which again one of the QRA method for risk assessment. This will be discussed into the module 2 accident modeling, risk assessment, management and HSE course in NPTEL IIT Madras.

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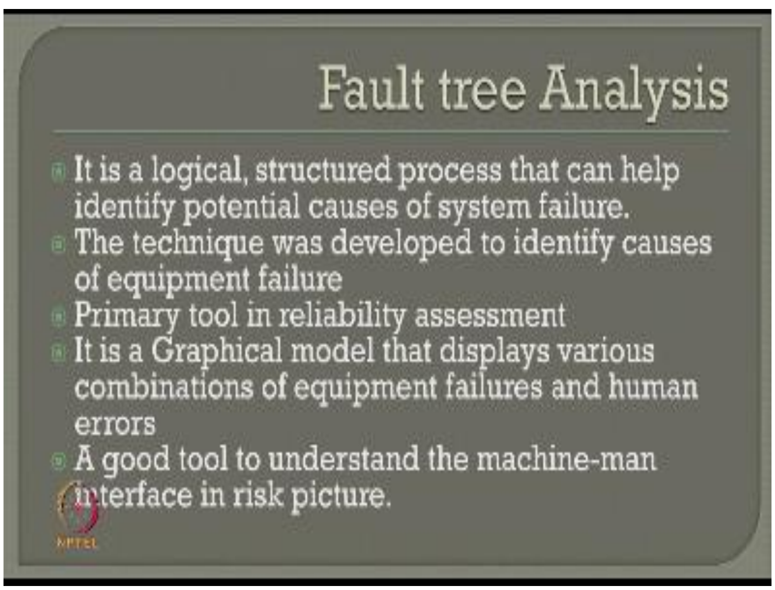

Let us quickly see some of the basics of fault tree analysis, fault tree analysis essentially is a logical structured process which can help to identify potential causes of a system failure. This technique was developed essentially to identify causes of equipment failure it is a primary tool which is still used currently in reliability assessment of mechanical failures. It is of course a graphical model which displays various combinations of equipment failure and human errors.

Friends it is one of the good tool to understand the machine-man interface in a given risk picture in oil and gas industry, especially the mechanical failures.

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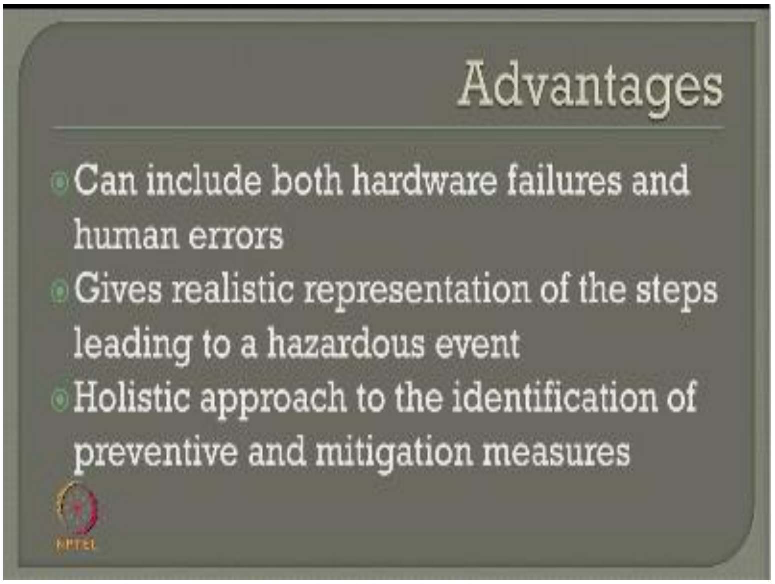

Fault tree analysis have got lot of salient advantages, it can include both hardware failures and human errors. One can ask me an alternate question when FTA can do and hardware analysis or failure in terms of the machinery and mechanical failures, what is the compromisation of this particular methodology with that of FMEA. FMEA does not handle essentially the man-machine interface whereas FTA can try to accommodate the probability of failure which is perceived as man-machine interface.

So this can include both hardware failure and human errors resulting from that failure. It actually gives a realistic representation of the steps leading to an hazardous event, it is a holistic approach to the identification of preventive and mitigation measures in a given system.

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Now the question comes where FTA can be applied, application of FTA is available or successful in the following areas. If you have got a system which is very highly complex and the system is highly redundant then analyzing such a complex system will generally be too difficult. FTA actually disintegrates this complexity in a very simple manner and try to analyze the risk picture in a more simpler technique.

So analysis of complex systems and highly redundant systems are most successful application for FTAs concerned, FTA generally is used in situations where another hazard evaluation technique has pinpointed the possible occurrence of an hazardous event which requires further investigation. So friends FTA can be seen as a micro-level tool which enhances the risk assessment when you in a specific focused window.

So any other parallel analysis like hazard etc, has available are evaluated on a hazard given system and recommended more in-depth analysis of risk assessment. Therefore, FTA follows the particular assessment has a secondary level analysis to make more detailed study on a given hazardous condition.

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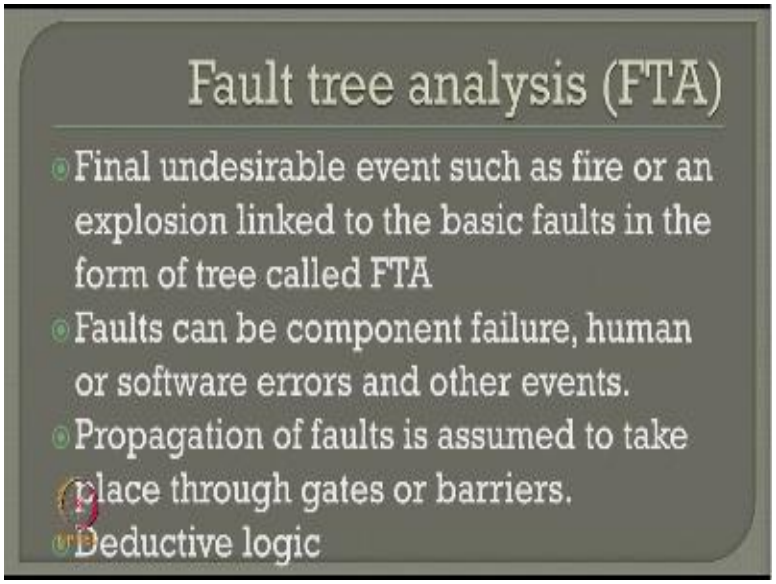

Fault tree analysis gives you a final output which is the final undesirable event for example, maybe fire or an explosion. This will be linked to the basic fault in a form of a tree called fault tree. So essentially the final outcome which can be an undesirable event like a fire on explosion will be resulting or emerging from series of faults in a given system which all will be linked in a form of a structure tree.

Therefore, this program or this analysis is technically called as fault tree analysis abbreviated as FTA. Now the faults can be component failure, it can be human interface or human error, it can be software errors, it can be other parallel events which can also result in an ultimate undesirable even like fire or explosion. The propagation of fault is generally assumed in this analysis to take place through the gates or what we call otherwise technically barriers.

Now the whole program of the analogy is actually inferred from deductive logic, you can get these algorithm in the logic from the given tree.

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Now let us quickly see how do we classify events which will participate in a given fault tree analysis. Now I have a final event which is undesirable for example, it can be a fire occurrence or can be an explosion etc that is a final event. There can be something called intermediate event which will lead to a final event or maturity of the final event. Of course, there are some basic events which are primarily responsible which will lead to the final event through the intermediate event.

So the presence of this equipment and the combination of intermediate event in support the basic given will all lead together to a final event in terms of a tree structure which we call as fault tree.

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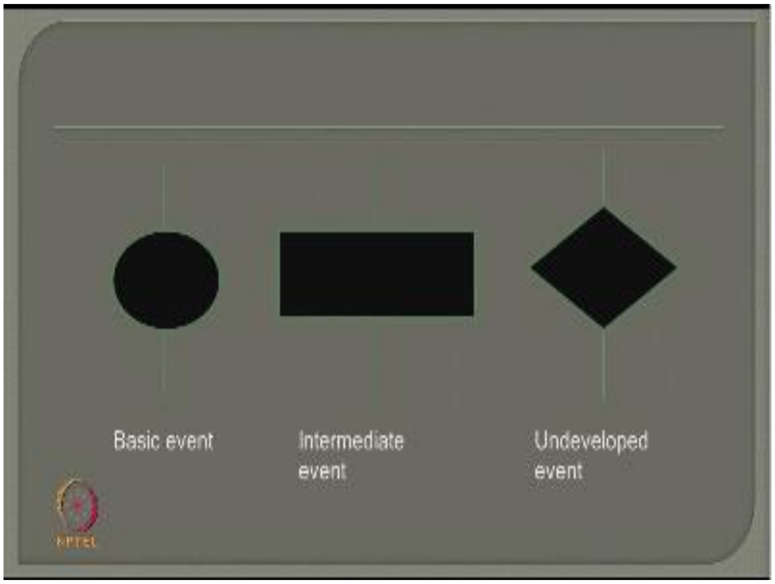

Now let us quickly see the symbols used in on fault tree analysis for three different levels of events one is what we call as an basic given is generally elliptical in shape and size, other is a rectangular box which we call as an intermediate event there are sometimes there can be something called undeveloped event which is generally indicated like a rhombus symbol in the given fault tree.

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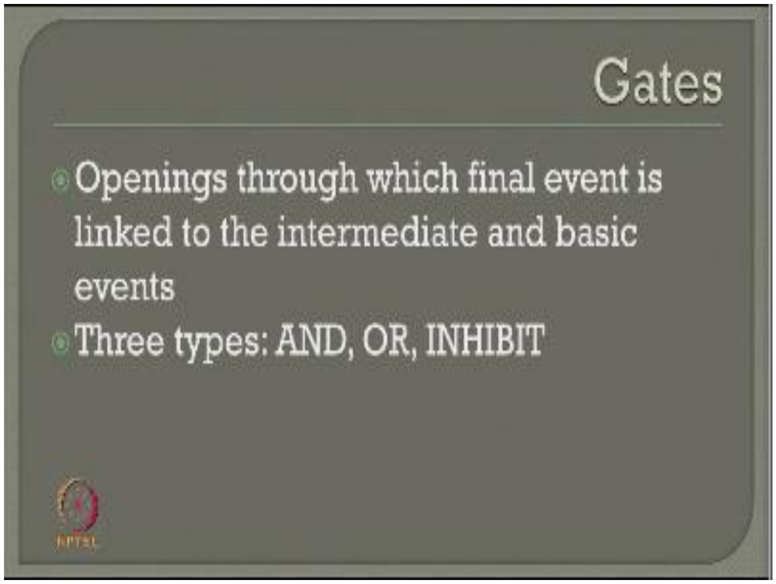

As I said in the beginning fault tree actually deduces the final event which is maybe undesirable through the steps of intermediate event which are originated from the basic events. Now the question comes how these events are connected. Now this is a tree in structure which are connected to gates. Now what are gates, gates are nothing about barriers or especially openings through which your final event will be linked to the intermediate and the basic events subsequently.

So gates actually form as connection points between the final event and the top intermediate and the basic events, there are three types of gates available in the logical tree structure of an FTA AND gate, OR gate and INHIBIT gate.

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Let us quickly see briefly what is an AND gate, let us say I have a final event now which can result from two intermediate events as you understand intermediate events will be represented by a rectangular box and the final event is also represented by a rectangular box whereas AND gate is represented by the symbol shown in the screen now. There are two input events for example even A and event B which can lead to a final undesirable or a final event.

Now it is very important that to get this event matured have occurred both this events need to participate that is why it is called an AND gate. Event A and event B put together will lead to undesirable event which is final event, therefore the final event is connected to the intermediate events through an AND gate whose symbol is shown in the screen now.

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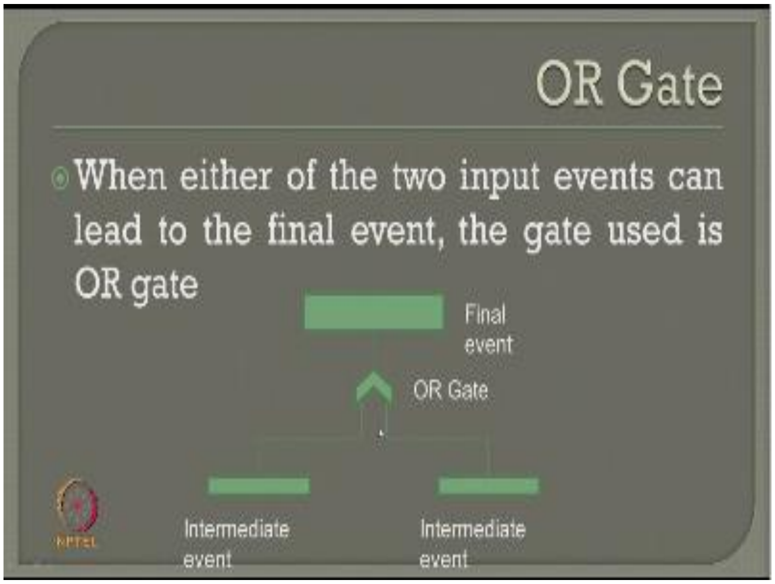

Alternatively there can be something called as an OR gate which is indicated by an arrow structure like this. Let us say there are two events A and B which are intermediate events of course intermediate events will receive basic events connectivity which we will see subsequently later. But intermediate events now will be responsible which will be subsequently connected through the gate to a final event.

Now if this is an OR gate in that sense it means either one of them is responsible to create the final event. So either A or B will be responsible or should be present to make the final event occur. So when either of the two input events are present which can lead to the final event then one can use a gate which is called as an OR gate.

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The third kind of gate is can INHIBIT gate. Let us say I have an intermediate event, I have a final event I want to connect the final event in a logical tree structure to the intermediate event through an INHIBIT gate. INHIBIT gate has got a specific condition, now if this condition is available then this event will lead to a final event. In the absence of this INHIBIT condition this event will not lead to a final event.

So this is a conditional occurrence of success of the final event in the presence of this condition intermediate event will lead to the final event. If you want to communicate this algorithm in terms of the tree structure one can use an INHIBIT gate. Therefore, if some constraints are inhibiting conditions need to be expressed in a given logical tree or need to be stipulated for the event to occur then you connect the final event or bridge the final event to the intermediate event through a gate called INHIBIT gate as shown in the screen now with this symbol.

So there are three kinds of gates which connect the final event to intermediate and that of the basic events. One is AND gate both events are necessary or all number of events are necessary to cause a final event, the other is an OR gate either one of them sufficient enough to cause the final event, the third one is an INHIBIT gate which expresses certain constraints and evenly conditions which may lead to the success of the intermediate to follow final event provided this INHIBIT conditions are completely met as stipulated in this tree structure.

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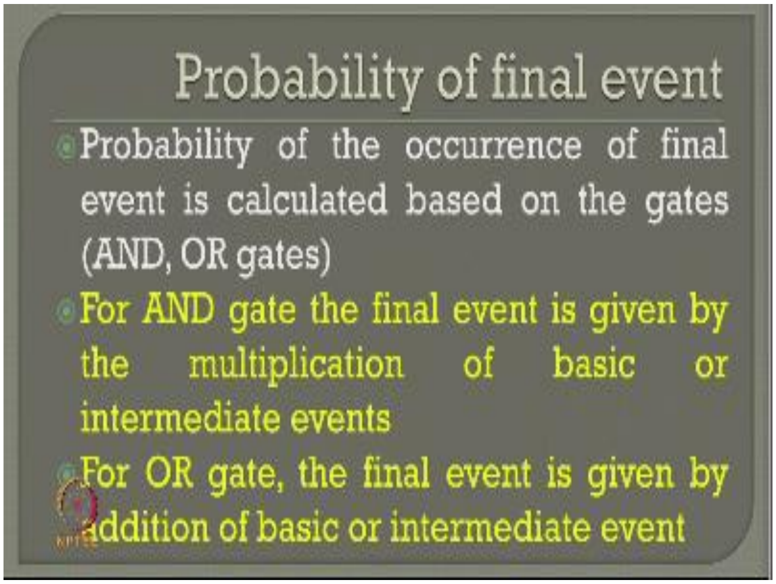

Now one is interested to finally see the outcome of probability of success of the final event, let us say the final event is a fire or an explosion one would like to see what is the probability of success of this occurrence of fire or explosion. So let us see what is the probability of a final event, probability of occurrence or success of the final event is calculated based on the gates which is connecting the final element to the intermediate event.

Now the gates can be either an AND gate or an OR gate for an AND gate final event is given by the multiplication of the basic or intermediate events. Whereas for an OR gate it is summation of the basic or the intermediate events.

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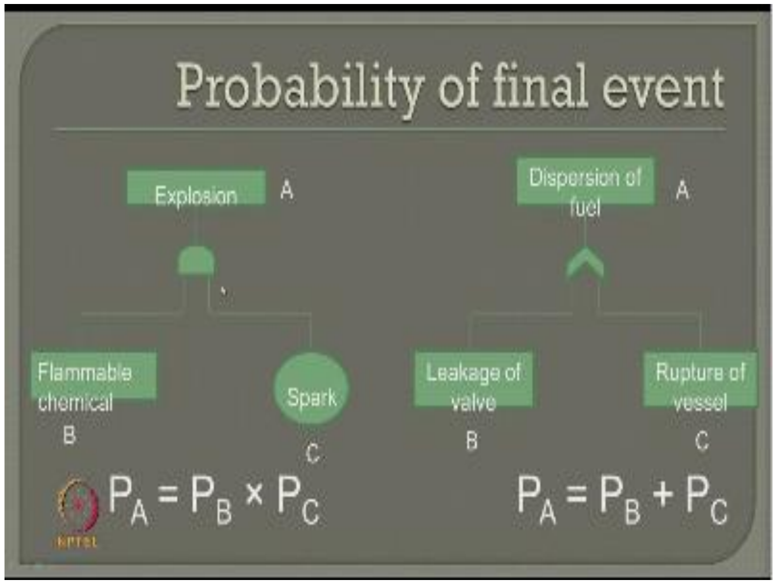

For example, if I have a final event as explosion the probability of explosion can arise flammable chemical & Spark has two intermediate or basic events because this an intermediate event, this can be a basic event where the symbol is elliptical here where is rectangular here. So in that case if I say I am connecting these two events to the final event by an AND gate because the symbol indicates an AND gate, in that case the probability of occurrence or success of explosion is the product of probability of flammable chemical present and the probability of spark present in the given system.

So it is a product of these two probability which will give me the probability of occurrence or success of occurrence of explosion. Whereas let us take the right hand side example, I have dispersion of fuel as event A which can be a final event I will interested in working out what is the probability of success of this event A occurring which is PA. If I try to connect two intermediate events because the rectangular symbol shows they are intermediate events.

If I am connecting these two intermediate events as leakage of valve B or rupture of vessel C as two events B and C if I am connecting these two events to the final event or end event through an OR gate in that case the probability of success of dispersion of fuel will be a summation of these two because either of them is important to occur this particular final event. So for an AND gate it is a product of the probabilities of the events participating for the OR gate it is summation of the probabilities of the events participating which will give me the probability of occurrence of the final event, in this case dispersion of fuel, in this case the explosion of the fuel.

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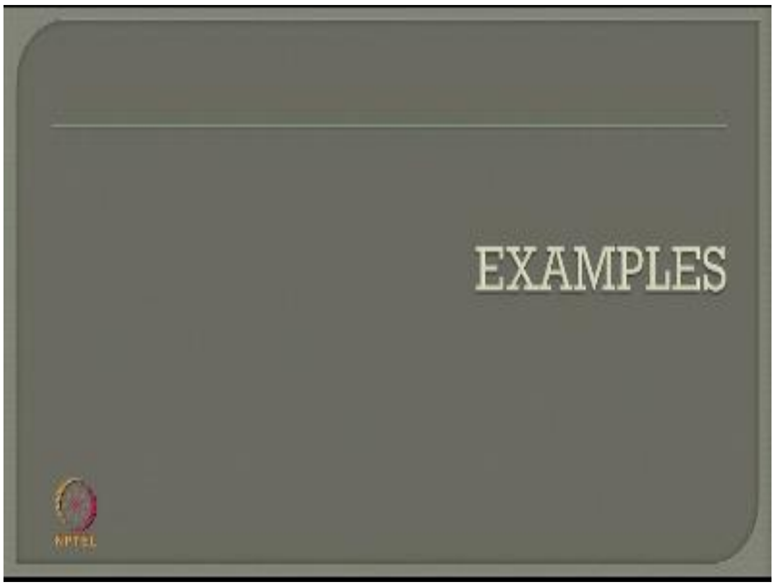

Let us quickly see couple of examples which are taken and borrowed from literature which have referred back at the end for acknowledgement.

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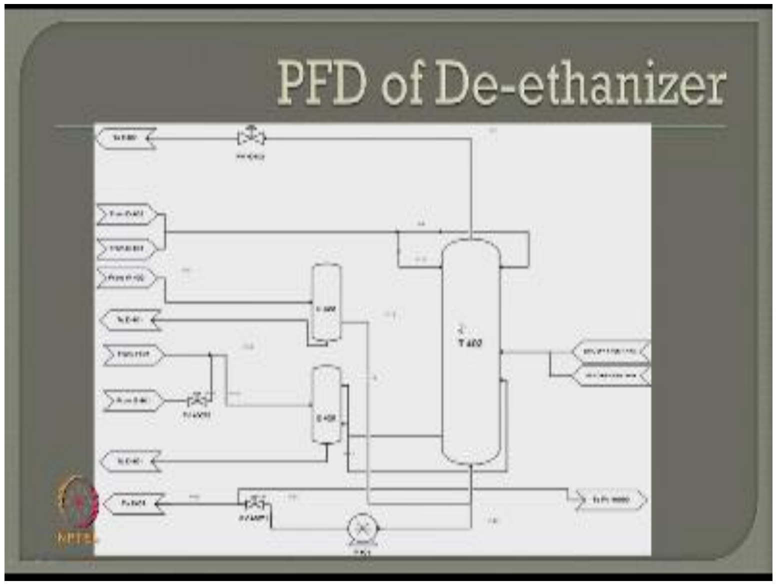

Let us quickly see a process flow diagram of De-ethanizer which is shown in the screen now. There are different events which are connected and they are coded as e407, d402 which are technically part of the process flow diagram of de-ethanizer.

They are connected by a different kinds of arrangements as you see in the flow diagram there are some non-return valves, there are some pressure regulatory valves, there are some tankers, there are some regulatory agencies which are connected, and based upon the process available e402 tanker there are some discharges which are taken back as a back feed supply e420 or e422 which are emerging recipient tankers or that can be also a feed-forward loop from e407 which is pumped by P401 to the tanker 402 for maintaining the stability and equilibrium of the chemical process in t04 to 402.

So let us quickly understand the process flow diagram as it is available on the screen now and try to now use an FTA algorithm to model this.

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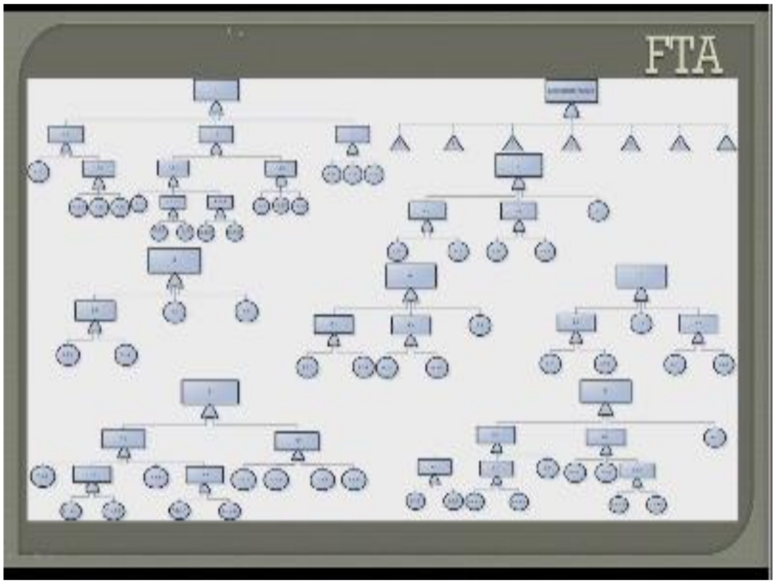

There is an example of FTA available for this particular example. Let us say now the fault tree analysis shown in the figure here one can see the rectangles indicate here or the intermediate in the final event whereas elliptical structures indicate here or the basic events. Now the final event can be connected to the intermediate events either by an AND gate or an OR gate as we saw in the previous case.

Now for example any intermediate event can also be connected to a basic event and one more intermediate event all these numbering structures are given in such a form for example the final event is 1 is 1.1 because this is leading to a final event. And similarly, the 1.1 intermediate event is receiving input from the basic event 1.1.1 and again a subsequent intermediate event 1.1.2. Now one can see here the intermediate event 1.1.2 is further receiving input from basic events 1.1.2.1.

For example, the numbering of these events derive the second subscript from the previous intermediate event, for example if the final event is 1 all the first subscripts in this will be 1 if the intermediate event is 1.1 the subscripts of this will become 1.1.1 and 1.1.2, if the intermediate event is 1.1.2 then the basic events will get subscripts as 1.1.2 then 0.1.2.3 and so on. One can see it very clearly that for success of 1.1 either 1.1.1 or 1.1.2 is important.

For success of 1.1.2 either 1.1.2.1.2.1.2.3 are important because they are connected by an OR gate. Whereas an example of 1.2.2 connecting basic evens 1.2.2.1.2.3 are connected by an AND gate. So it is important for us to understand such as 1.2.2 depends on success of 0.1.1.3 and all of them to become parallely. So if you want to compute the probability of occurrence of success of this event I must multiply the probability of occurrence of these whereas in this case I have to add the sum of these to get the probability of occurrence of this.

So ultimately your tree structure will lead to the probability of occurrence of success of this particular event which is branching from 1.1 which is branched here 1.2 which is branched further here or 1.3 which is branched here. So it is a very classical example of different structures as 1 similarly 2, 3, 4, 5 which are different segments available in the process flow diagram. Now let us quickly see the experimental expansion of these particular events in a tabular form.

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SL. No.	Deethanizer failure	Fault tree ref	BE failure rate
1	Power failure from source (Mobin)	1.1.1	Linguistic term
2	Breaker failure	1.1.2.1	Failure rate
3	Transformer failure	1.1.2.2	Failure rate
4	Human error to stop the pump (P-401)	1.1.2.3	Linguistic term
5	Poor PM (planning and control) (P-401)	1.2.1.1	Linguistic term
6	Lack of supervision (P-401)	1.2.1.2.1	Linguistic term
7	Lack of competency of maintenance workers	1.2.1.2.2	Linguistic term
8	Procurement inadequacy	1.2.1.3.1	Linguistic term
9	Lack of supervision and inspection by asset integrity dept.	1.2.1.3.2	Linguistic term
10	Icing due to dryers deficiency (Suction P-401)	1.2.2.1	Linguistic term
11	Hydrate formation (Suction P-401)	1.2.2.2	Linguistic term
12	Chocking of strainer (Suction P-401)	1.2.2.3	Linguistic term
13	Lack of knowledge (Training)	1.3.1	Linguistic term

Let us say the failure fault tree reference is 1.1.1 let us go back here, which is 1.1.1 a basic event this particular event refers to power failure from a source mobin cabin.

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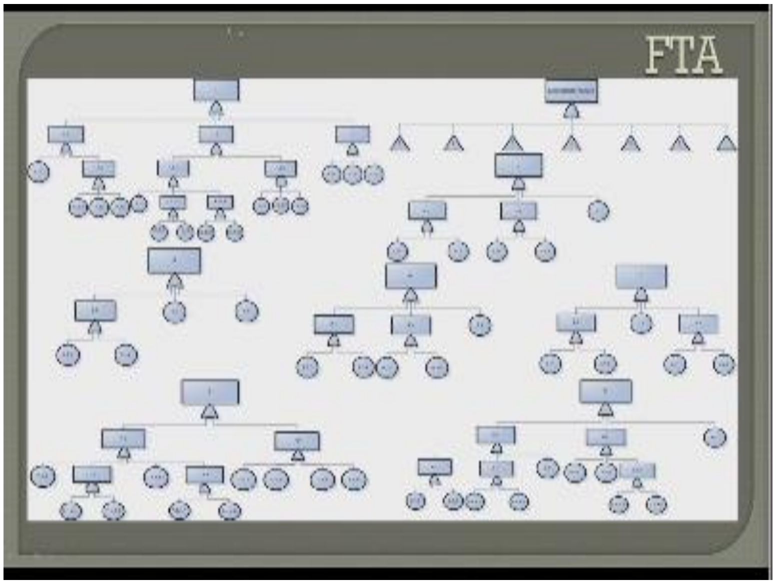

Similarly the power failure let us quickly see how 1.1.2 will be connected to .1.2 and .3 let us quickly see where is 1.1.2.

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SL. No.	Deethanizer failure	Fault tree ref	BE failure rate
1	Power failure from source (Mobin)	1.1.1	Linguistic term
2	Breaker failure	1.1.2.1	Failure rate
3	Transformer failure	1.1.2.2	Failure rate
4	Human error to stop the pump (P-401)	1.1.2.3	Linguistic term
5	Poor PM (planning and control) (P-401)	1.2.1.1	Linguistic term
6	Lack of supervision (P-401)	1.2.1.2.1	Linguistic term
7	Lack of competency of maintenance workers	1.2.1.2.2	Linguistic term
8	Procurement inadequacy	1.2.1.3.1	Linguistic term
9	Lack of supervision and inspection by asset integrity dept.	1.2.1.3.2	Linguistic term
10	Icing due to dryers deficiency (Suction P-401)	1.2.2.1	Linguistic term
11	Hydrate formation (Suction P-401)	1.2.2.2	Linguistic term
12	Chocking of strainer (Suction P-401)	1.2.2.3	Linguistic term
13	Lack of knowledge (Training)	1.3.1	Linguistic term

1.1.2.1 may be a breaker failure, transformer failure and human error to stop the pump. So 1.1.2 and .3 can be connected together to lead to 1.1.2 so 1.1.2 success depends on either of these events if it is available or happening then 1.1.2 which will lead to the failure which is available 1.1.2 can also lead to the failure either from a breaker failure or a transformer failure or an human error.

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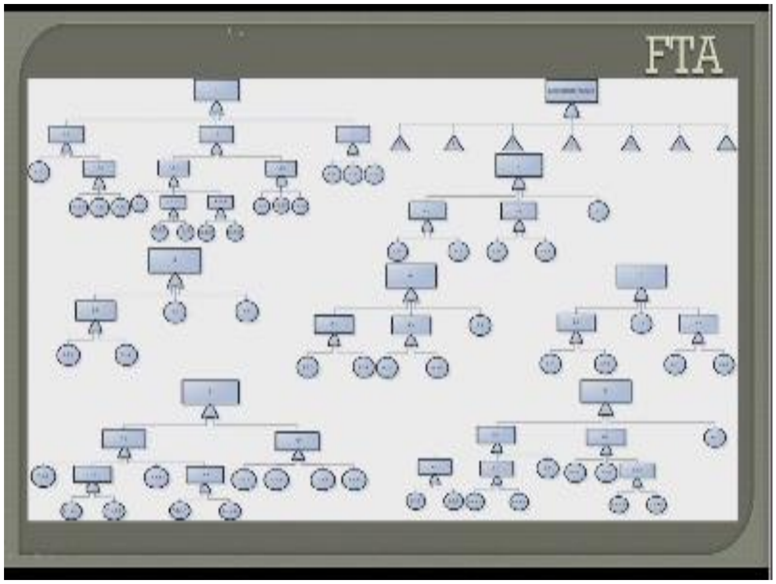

Similarly all the name is available here for different intermediate events, final event and the basic events in terms of 1, 2, 3, 4, 5, 6, and 7 are tabulated here.

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SL. No.	Deethanizer failure	Fault tree ref	BE failure rate
1	Power failure from source (Mobin)	1.1.1	Linguistic term
2	Breaker failure	1.1.2.1	Failure rate
3	Transformer failure	1.1.2.2	Failure rate
4	Human error to stop the pump (P-401)	1.1.2.3	Linguistic term
5	Poor PM (planning and control) (P-401)	1.2.1.1	Linguistic term
6	Lack of supervision (P-401)	1.2.1.2.1	Linguistic term
7	Lack of competency of maintenance workers	1.2.1.2.2	Linguistic term
8	Procurement inadequacy	1.2.1.3.1	Linguistic term
9	Lack of supervision and inspection by asset integrity dept.	1.2.1.3.2	Linguistic term
10	Icing due to dryers deficiency (Suction P-401)	1.2.2.1	Linguistic term
11	Hydrate formation (Suction P-401)	1.2.2.2	Linguistic term
12	Chocking of strainer (Suction P-401)	1.2.2.3	Linguistic term
13	Lack of knowledge (Training)	1.3.1	Linguistic term

For different description of failure ultimately event 1 which you see here.

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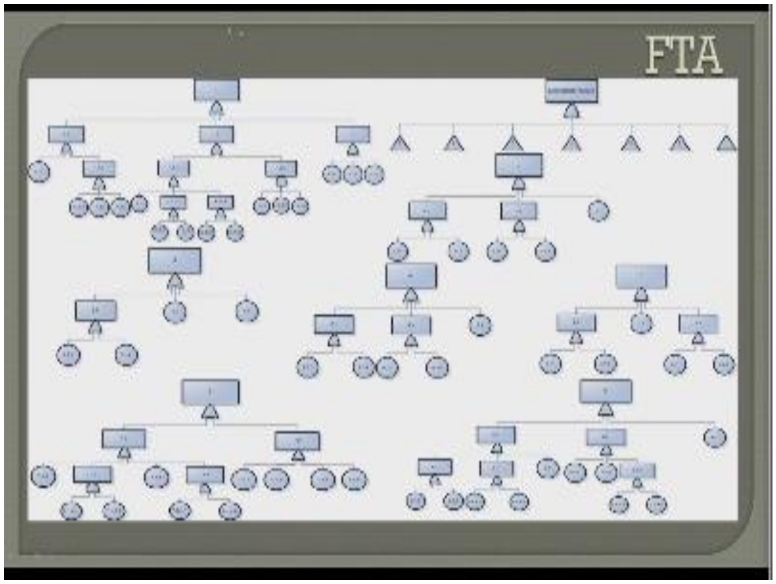

Is actually the de-ethanizer failure of the whole process.

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S. No	De-ethanizer failure	Fault tree ref	BE failure rate
14	Lack of skill (experience)	1.3.2	Linguistic term
15	Lack of perception/carelessness	1.3.3	Linguistic term
16	Loss of IA from source (Mobin)	2.1.1	Failure rate
17	Human error to close the IA valves in plant/offsite battery limit	2.1.2	Linguistic term
18	Equipment Failure (FIC of FV-40071A)	2.2.1	Failure rate
19	Loose connections in IA network (FIC of FV-40071A)	2.2.2	Failure rate
20	Human error in DCS to close the FV	2.3	Linguistic term
21	Failure of C-501 due to poor PM	3.1	Failure rate
22	Internal (inside erosion) (E-420)	3.2.1	Failure rate
23	External (humidity) (E 420)	3.2.2	Failure rate
24	Equipment failure (TIC of TV-40075)	4.1.1	Failure rate
25	Loose connections in IA network (TIC of TV-40075)	4.1.2	Failure rate
26	Failure/error of PIC (PV-40102)	5.1	Failure rate

Now once I will refer this for different kinds of failure which are connected logically using a tree which is fault tree.

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SL. No.	De-ethanizer failure	Fault tree ref	BE failure rate
40	Bad manufacturing (supports)	7.2.1	Failure rate
41	Poor welding (supports)	7.2.2	Linguistic term
42	Vibration (supports)	7.2.3	Failure rate
43	Lack of fire proofing in case of fire in adjacent area (supports)	7.2.4	Linguistic term
40	Bad manufacturing (supports)	7.2.1	Failure rate
41	Poor welding (supports)	7.2.2	Linguistic term

Ultimately I will just try to find out what would be the probability of failure.

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Failure probabilities of basic events

BEs	FP of BEs	BEs	FP of BEs	BEs	FP of BEs	BEs	FP of BEs
1.1.2.1	0.01	3.2.1	0.012	6.1.1.2	0.009	7.1.1	0.017
1.1.2.2	0.015	3.2.2	0.008	6.2.1	0.011	7.1.3	0.02
2.1.1	0.002	4.1.1	0.014	6.2.2	0.0065	7.1.4.1	0.019
2.2.1	0.014	4.1.2	0.009	6.2.3.1	0.017	7.1.4.2	0.006
2.2.2	0.018	5.1	0.013	6.2.3.2	0.005	7.2.1	0.015
3.1	0.02	5.1.1.1	0.014	6.3	0.023	7.2.3	0.012

The failure probability of total event is found out to be 0.3024 per year.

To understand the probability of failure I must first assign failure probabilities of the basic events, because you know the failure probability of the whole event depends upon either sum of the events of the basic or product of these events of the basic, how are they connected to the gate to the intermediate of the final event.

Therefore, each one of these events which are basic events or then assigned to failure probability in terms of a number varies from 0 to 1 and these numbers are actually assigned based upon the experiences and the walk and surveys conducted in the plant and once you identify them and feed them in the fault tree the failure probability of the total event which is number one which is de-ethanizer failure is identified and calculated to be found to be as 0.3024 per year. So 30% probability of failure is matured enough to understand this kind of failure.

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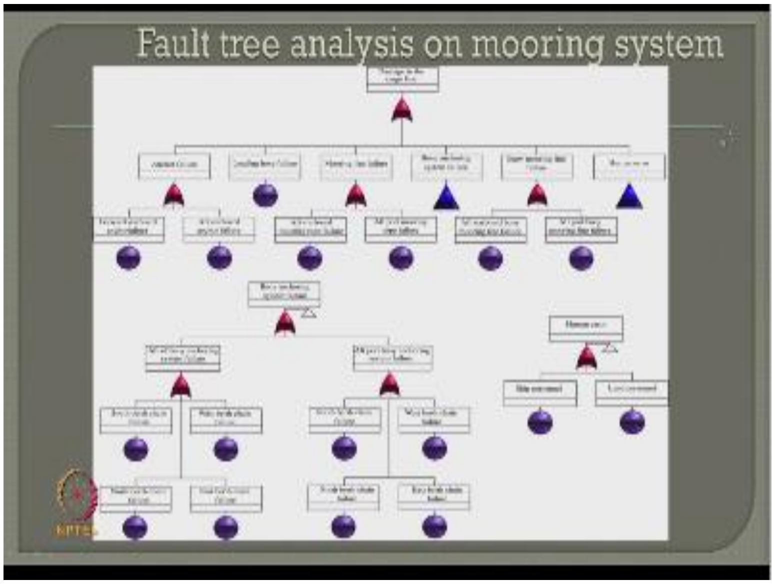

The second example what you see here the screen is on a mooring system. Now the mooring system I think it is designated as damage to the cargo line because the mooring system is completely disconnected it will lead to damage the cargo line again there are different kinds of events connected intermediate, basic, and final events which are connected by different kinds of gates.

Now there are some conditions available in certain areas where we call them as intermediate conditions which can be feed to the direct sustainability of this buoy anchoring system failure. So buoy anchoring failure may not have any connectivity with any of the basic systems, but it can alone fail because of the system failure on a buoy anchoring system. Now any one of these failure lines for example human interface buoy mooring line failure, buoy anchoring system failure, mooring line failure in terms arising from the roof failure or the row failure or the port mooring failure or the anchor fail.ure can lead to the ultimate damage of the cargo line.

So the whole accessories of the mooring system failure is being divided in different segments one is what we call damage the cargo line, the other can be the buoy anchoring system failure, the third alone can be human error which comes from the ship personal or from the land personal, because of miscommunication between these particular team. So now I, as we saw in the last example.

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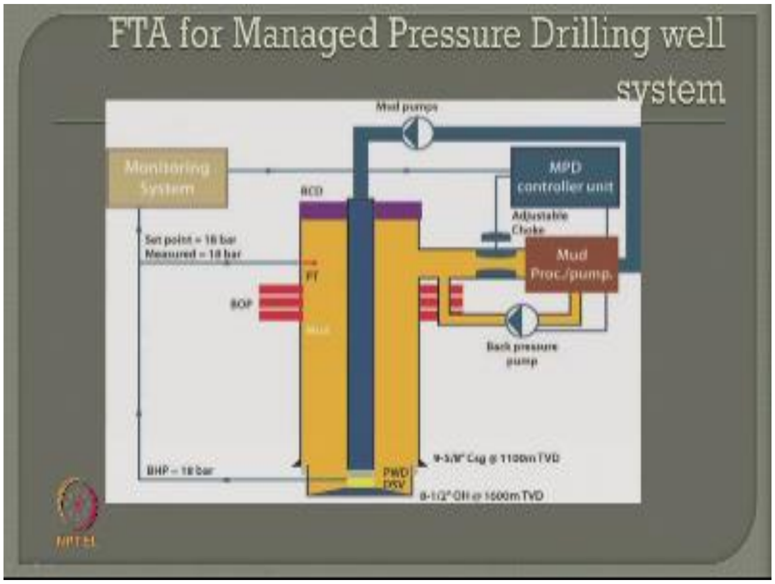

We will now assign different kinds of failure probability with each one of them.

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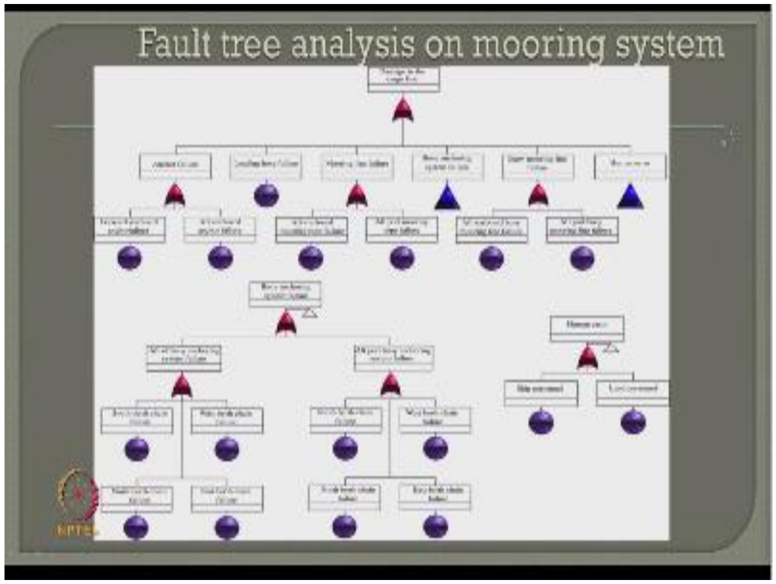

Based on the experience and one can calculate what would be the maturity value of the probability of success of the final event.

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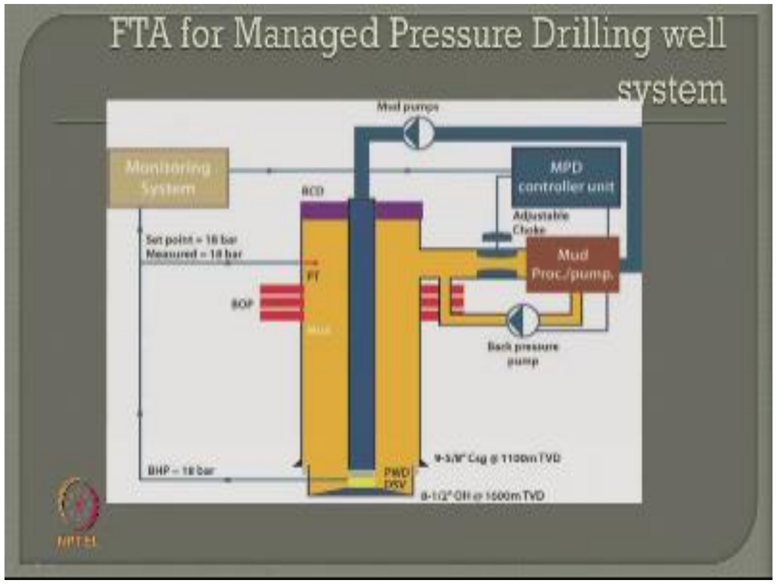

Now one can also see a fault tree analysis for a managed pressure drilling well system which you see in the screen now.

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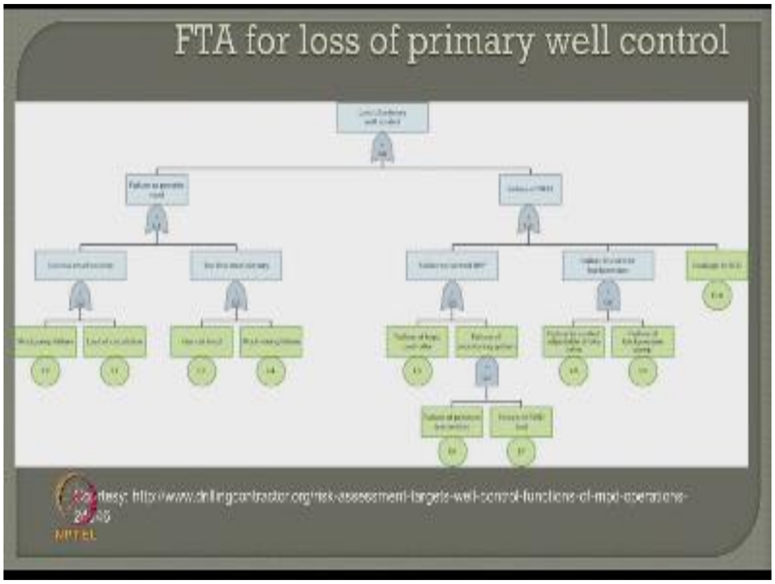

There can be a loss of primary well contain which is leading to an accident so loss of primary well control is connected to failure to provide mud or failure to MPD which can be further connected to low mud volume or low blood density whereas the failure of MPD can be connected to failure over control BHB, failure to control back pressure or sometimes even connected to leakage in the refinery itself.

So these events can again borrow values from the basic events e1 and e2, e3, e4 etc, one can assign failure probability with each one of them separately which can ultimately lead to either through an OR gate or through an AND gate so were one can either find out the probability by summation of these events or the product of these events as we saw in the last slides.

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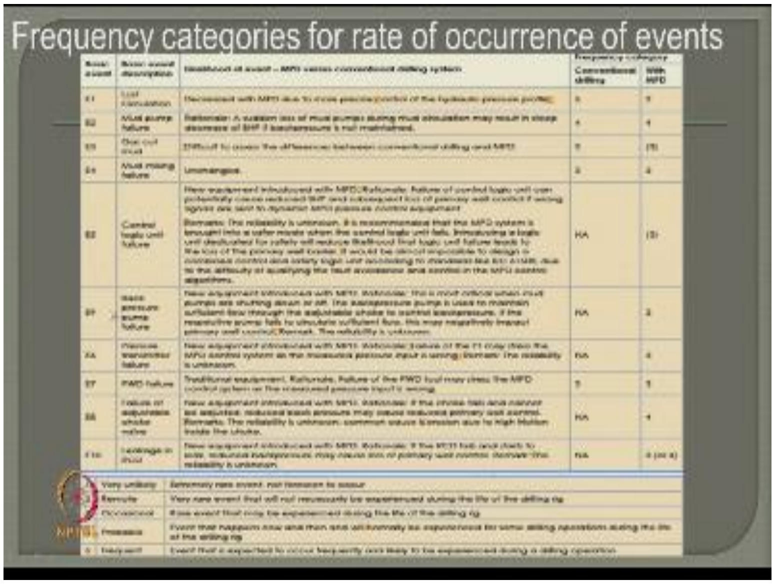

So once we do that frequency categorization for rate of occurrence of events in terms of basic humans of e1, e2, e3 which you saw in this particular slide.

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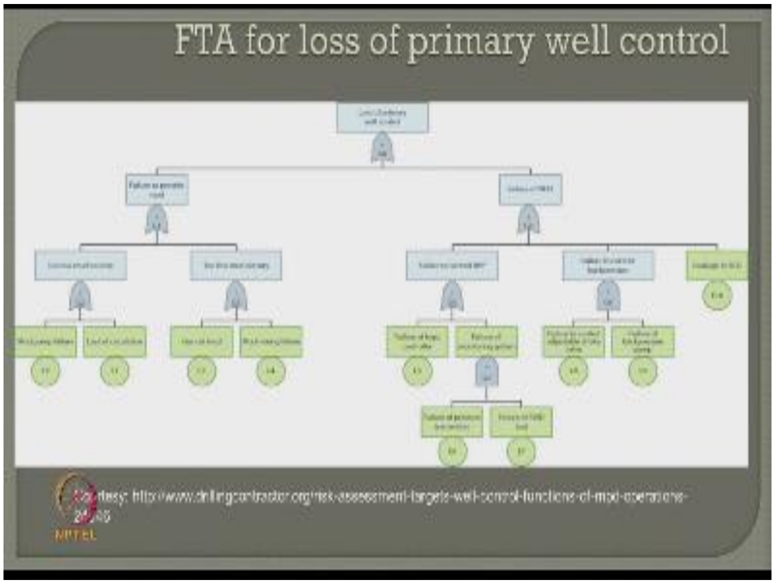

As e1, e2, e3, e4 is being designated.

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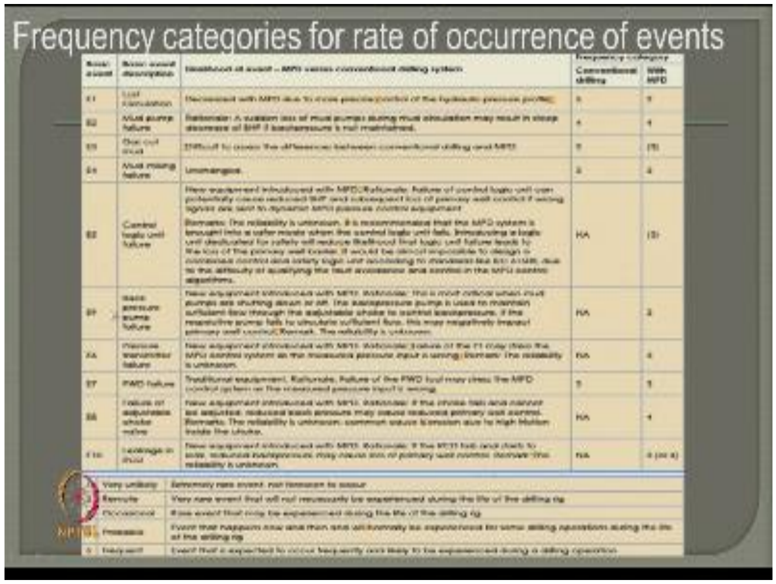

And the basic event description has being given here based on which the conventional drilling frequency category is been done with infinity is been done. Therefore, one can always indicate these numbers qualitatively as one is very unlikely whereas ϕ is very frequent.

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Parallely one can also do what we call ETA which is called event tree analysis.

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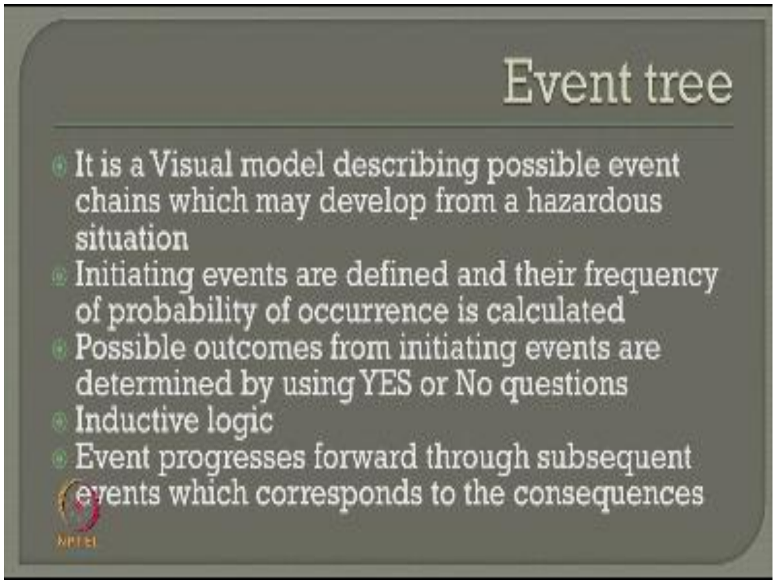

Event tree actually is a visual mode describing possible event chains which may develop from a hazardous situation. Initiating events are defined in the frequency of probability of occurrence is subsequently calculated. Possible outcomes from initiating events are determined by using yes or no questions. It is actually inductive logic whereas fault tree analysis was an deduce in logic. Event progresses forward through subsequent events which corresponds to the consequences arise from the failure modes.

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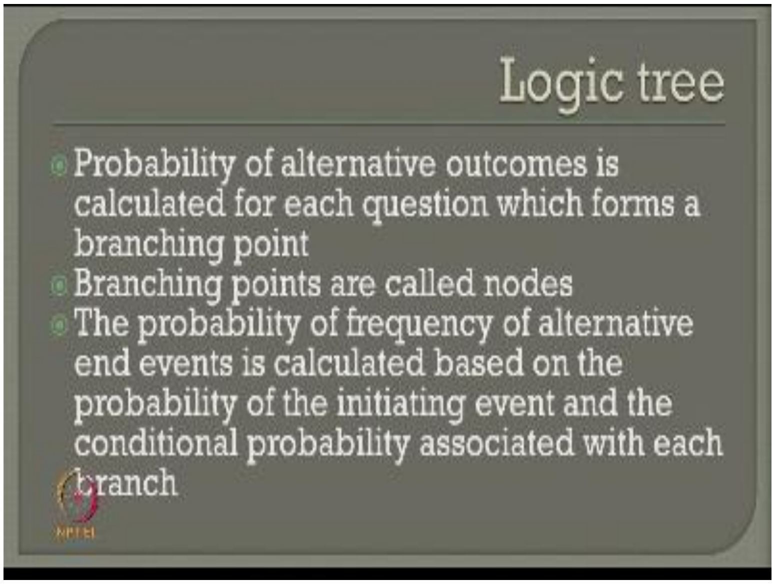

Event tree is again connected for the logical tree. The probability of alternate outcome is calculated for each question which forms a branching point of a particular tree. These branching points are called as nodes in the analysis. The probability of frequency of alternative end events is calculated on the basis of probability of initiating event and the conditional probability associated with each branch of the particular system.

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ETA has certain advantages.

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The frequency calculation for consequence classes are much simpler in ETA. Essentially ETA can be used for sensitivity analysis in oil and gas industries. It is useful to identify major contributions for each consequence class. Fatality risk assessment is more comfortably done using event tree analysis.

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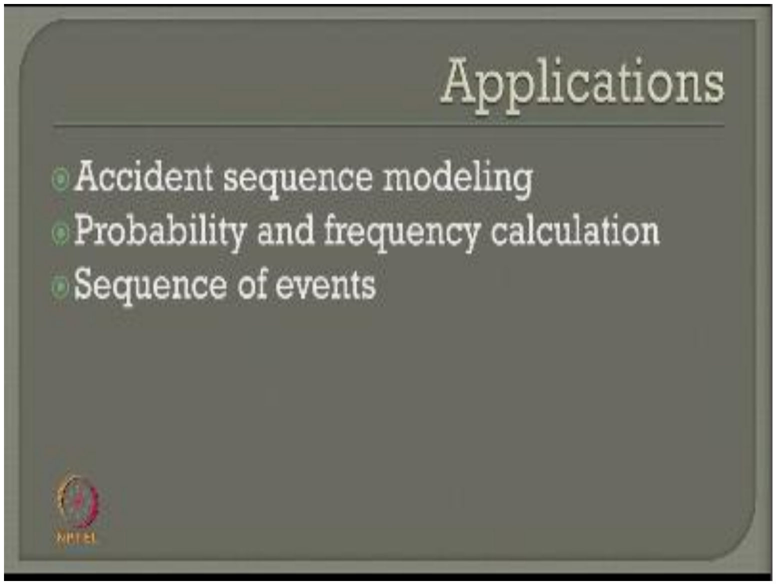

It can be applied on the following segments, accident sequence modeling, probability and frequency calculations, sequence of events and so on.

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Let us quickly see how do we classify initiating event frequency. Let us talk about process leaks, let us talk about riser and pipeline leaks, let us talk about blowouts. These are some of the interesting initiating frequency events which can be leading to a failure of a drilling unit.

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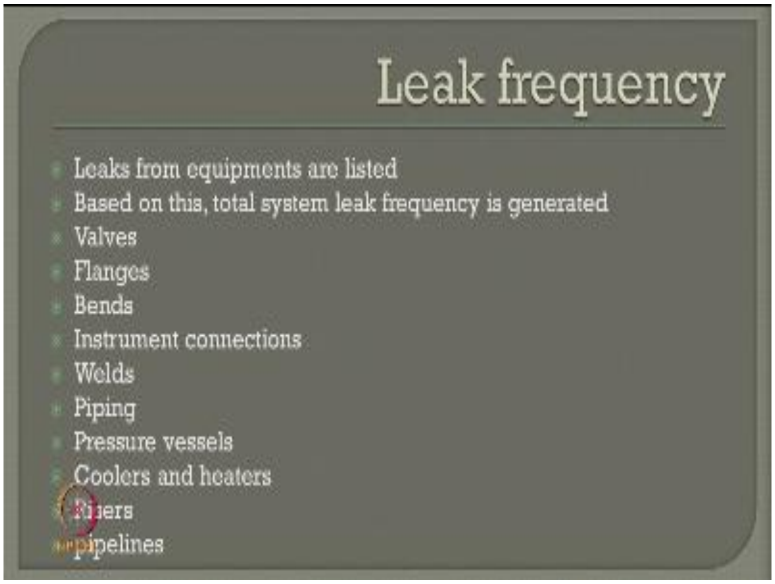

The leak frequency can arise from equipments which are listed below, based on this listing the total system leak frequency can be then generated. What are the possible leaks from equipments, it can be from the valves, it can be from flanges, it can even bends, instrument connections, welds, piping, pressure vessels, coolers and heaters, risers and pipelines.

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Leak frequency if you want to work over for blowouts then the following operations need to be considered separately. Shallow gas zone drilling, exploration drilling, well testing, development drilling, completion of production wells, completion of injection wells, regular production system, wire line operations, coiled tubing operations, which is done through umbilical's and snubbing operations sometimes then for blowout preventer wells. Somehow sometimes one can also leak frequency which arise from work over operations during the shift.

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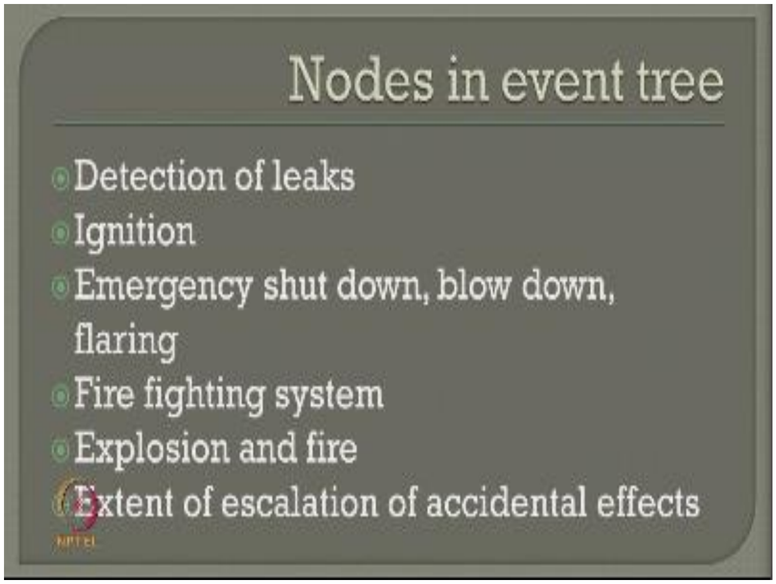

We also spoke about the branches in a given logical tree where we are identifying the events in a given system. Let us talk about what are nodes, nodes actually are the points where the leaks are detected. Therefore, wherever there is a leak detection possible we classify them as a note. Wherever ignition is possible because that is one of the important source for fire explosion we can also identify them as a node.

Then we have got location of emergency shutdown valves, blow down preventers, flaring stack points etc, they can also become important modes in a given event tree, if you all got external fire fighting system which can be invoked upon a supportive system for fire control, then those nodes can also be considered in the event tree. And if you have got any system externally like sprinklers, deluge etc, which can be used for fire and explosion prevention of medication even these points can also be used as important notes the given event tree.

If you can also have extent of escalation of external effects which you cannot give an interface feedback in a given node the response can also be taken as nodes in a event tree.

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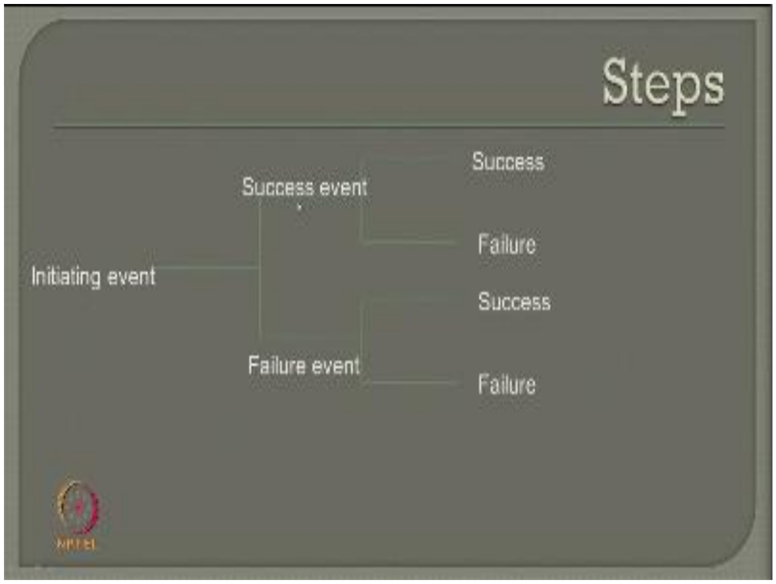

Let us quickly see some of the steps involved in an event tree analysis, let us say I have got an initiating event, the initiating event can be successful, can be a failure if it is successful then it will lead to another successful event, it can also again lead to a failure event. So one can always see an initiating event can branch out many successful events or subsequently many failure events.

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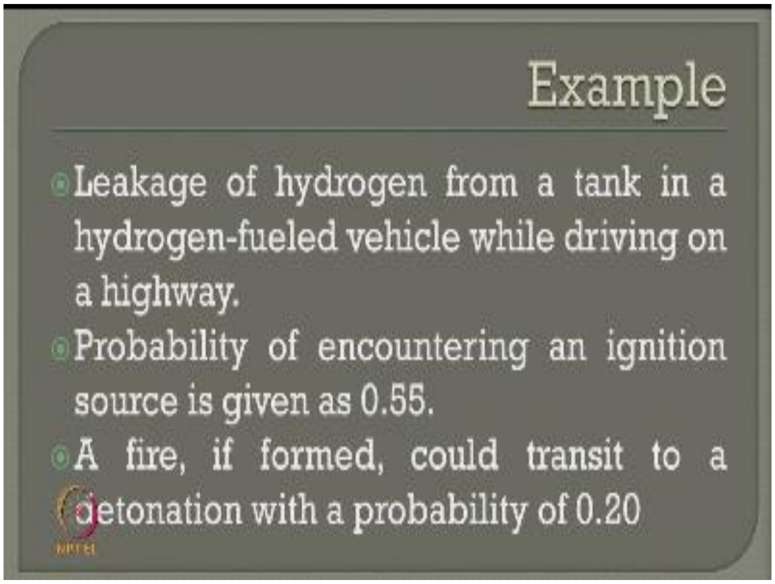

Let us take an example and try to see, let us talk about leakage of an hydrogen from a tank. In a hydrogen fueled vehicle while driving on a highway, probability of encountering an ignition source is given as 0.55, whereas a fire, if formed, could transit to a detonation with a probability of 0.20 as an input data for this analysis.

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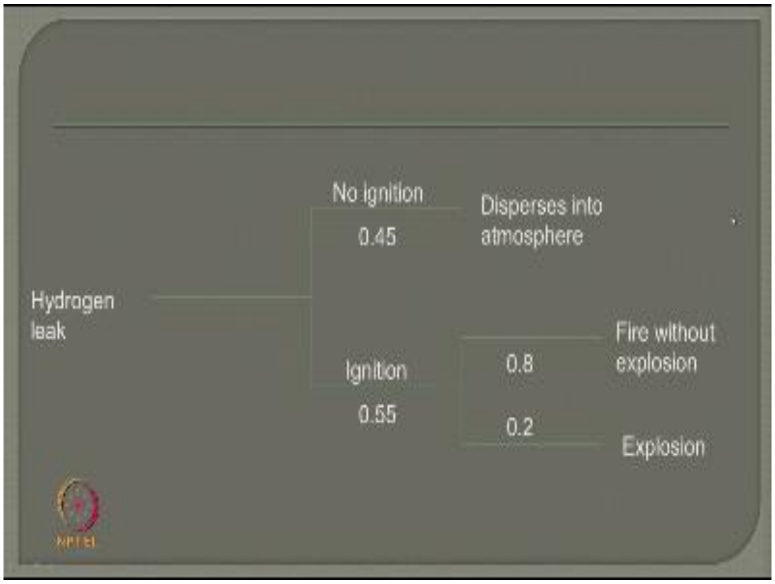

So let us say hydrogen leak, possibility no ignition, ignition possible 0.55, so if it there is no ignition then the fuel, the leak fuel disposes into atmosphere, if it ignites then the possibilities are can be a fire without explosion, there can be fire with explosion. So these are possible branch outs which are events coming out from ignition and this one branch out coming out from no ignition which are branching out as events from a simple principle event which is hydrogen leak.

So event tree analysis actually looks into more detail of frequency of occurrence of events and the probability of failure very closely compared to the top fault tree analysis, et here therefore, looks intrinsically in terms of sequence of accidents whereas fault tree looks into the probability of success of the final event alone.

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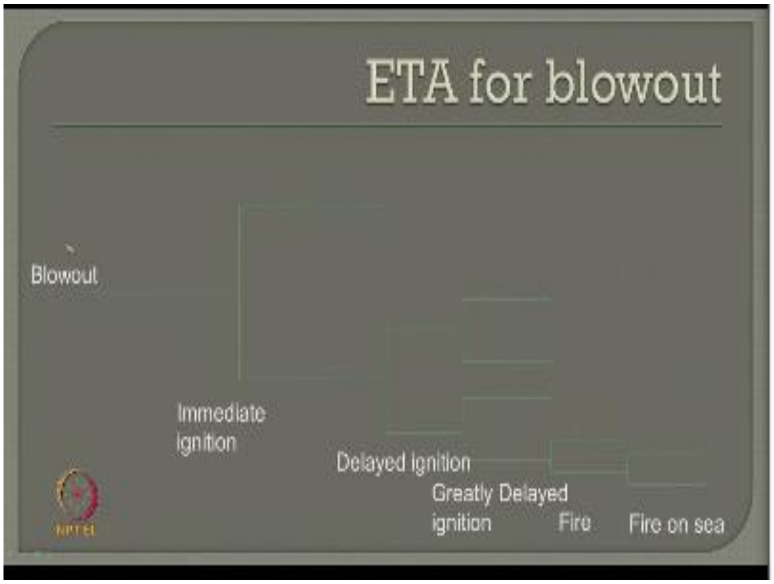

Let us try to draw a blow ETA for a blowout, blowout can have a two branches immediate ignition, the immediate ignition can also have a delayed ignition, greatly delayed ignition can result in fire or can be fire on sea. So I am not branching out the remaining events I am surely only one branch, so a simple blow can lead to a lot of intrinsic discussions which leads to ultimately fire which happens from the blowout.

But before the fire is ultimately matured is a final element you can see the intrinsic explanations given for arriving at the final event compared to that of a basic event. So this kind of detailed analysis is a substitute which is not available in a fault tree analysis.

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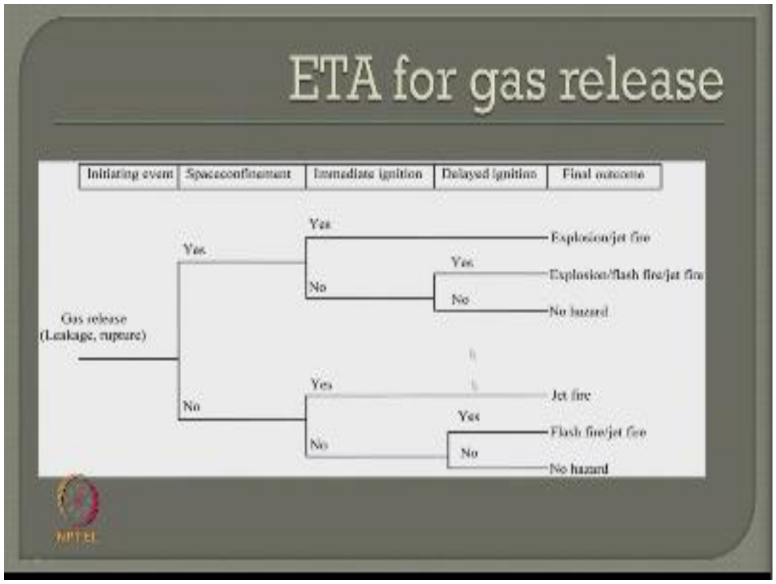

If you look at the ETA for a gas release, let us say gas release can arise either from a leakage or from a rupture. If the gas release arises it can lead to explosion, if the explosion is not possible then you can lead to explosion or jet fire or ultimately there can be no hazard, because you are able to control the leak rupture. If the gas release is not occurring in case of space confinement then if the immediate ignition is not there then delayed ignition is also not there, then you go you do not land up any hazard.

So one can see here a simple question of yes and no forgiven branches can always lead to different segments of the final outcome. For example, let us say gas release yes, space confinement is present immediate ignition is present, it will certainly lead to the explosion it is a final outcome. For example, in case of a gas release is there a leak rupture if the space confinement is yes, but immediate ignition is not present then delayed ignition is there it may lead to a flash fire.

The delayed ignition is not present is not result in the hazard. So event analysis or event tree analysis especially is actually deriving an outcome results from simple questions of yes or no which is asked on the initiating event or a basic event. So ETA is an intrinsic argument of exploration given to an occurrence of success of a specific event through simple questions of yes or no which can branch out to different segments in a given process which leads to the final outcome on a given problem.

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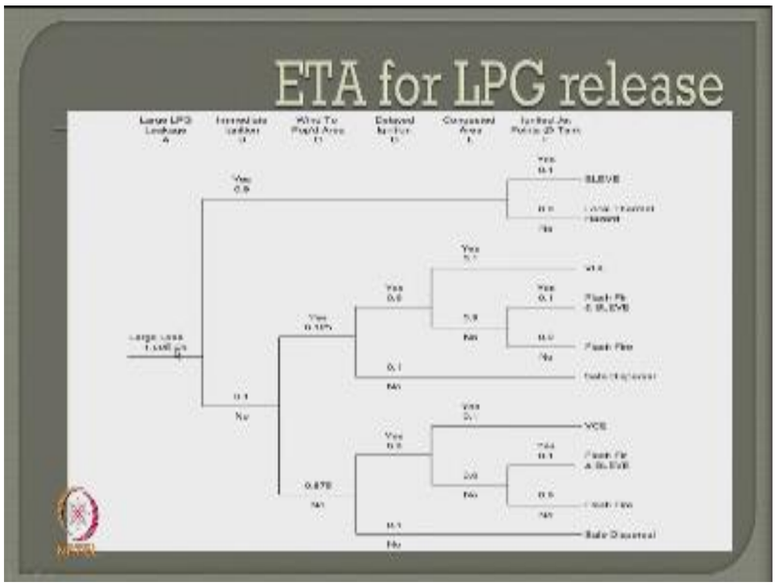

If you look at ETA for an LPG release one can always say large LPG leakage immediate ignition maybe sector B, we divide the entire plant in different segments like ABCDE as explained here. Let us associate probability of failure of occurrence of largely as 110^{-4} the probability of this leakage in terms of immediate ignition let us say the probability is 0.9 as yes and point 1 as no. If it is 0.9 as yes, then it is sum that divide to ignited jet points in the tank available as 0.1 because mostly you will try to control them using sprinklers etc.

Therefore, the possibility of this becoming a BLEVE is only 0.1 whereas the possibility of this leak becoming a local telling hazard can be very high. So simple yes or no questions which will lead to always from branches for sum as 1 you can see here the sum is 1, see here the sum is 1. So simply yes or no questions lead to other questions which will lead to an ultimate outcome will be intrinsic explanation given on a basic event maturity in terms of different segments which are seen in a process industry like an LPG release in this example.

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The study of course has specific reference has taken which I want to acknowledge here.

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So in this particular lecture we understood basics of fault tree and event tree analysis. We saw some update examples of fault tree analysis and event tree analysis. This lecture also compared the intrinsic arguments arise or the outcome arise from the event tree compared with our fault tree analysis, both of equivalent substitute methods for QRA available in any process industry nevertheless they are successfully applied to oil and gas industries, thank you very much.

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