Health, Safety and Environmental Management in Offshore and Petroleum Engineering
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Module – 03
Accident modeling, risk assessment and management
Lecture - 13
QRA application

Friends, let us talk about the QRA application problems.

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In Lecture 13, where you are going talk about some application issues in Quantitative Risk Assessments, in Module 3 where we are focusing on Accident modeling, Risk assessment and Management. We already said the last lectures that how one can handle different kinds of released scenarios like, fire and explosion model. We have also said what will be the consequences in case of fire explosion in terms of detonation, deflagration etcetera. We have also said how over pressure and negative pressure can create damage on an existing system because of explosion. We have also said how one can find equivalence at explosion damages using TNT equivalence you have given equations to estimate that. And we also said what would be the over exposure risk limit in a given system for fire and explosion accident models.

Subsequently followed by this we also discussed about toxic chemical release models, where we said that chemical exposure index will be one interesting domain by which we can easily estimate the consequences indirectly. It has got certain pre-requisites to do chemical exposure index. It also has certain advantages, and of course it is got certainly a few limitations. But of course, globally the dow CEI is acceptable as one of the powerful tool for estimating the damages which are envisage because of probable or possible chemical releases in a given process system.

Having said this interestingly there are many application issues when you talk about quantitative risk assessment. We already said risk analysis can be defined as a systematic identification.

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Let us get back to the original definition of risk analysis. Is defined as a systematic identification and description of risk this is very interesting. You have got to identify the presence of risk. You have got to describe what would be the risk, for example identifying does not mean it become a risk actually we have got to describe the risk in terms of personnel, property, and environment. So, it is a very broad term of risk analysis.

In property one can also include equipments, one can say asset. QRA which is quantitative risk assessment therefore need to be focused on the identification of applicable hazards, description of hazards to personnel, environment and equipment.

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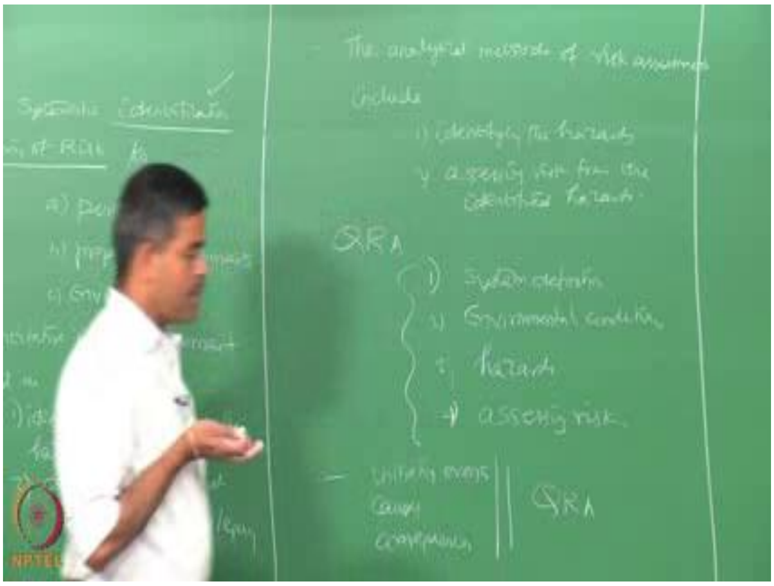

Therefore, analytical methods of risk assessment include identifying in the presence of hazards and then assessing risk from the identified hazards. If you look at the flow chart of risk assessment the first step obviously should be a system definition, then identifying the environmental conditions, then identifying the possible hazards, then from the possible hazards really session of num in terms of assessing risk. While doing so one need to identify the initiation or initiating events, causes and consequences.

These are important parameters, let say gauge marks in QRS. As we now agree in risk assessment the foremost step is to identify the hazard after you describe the system. After describing the system you identify the hazard first.

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So, what we call as hazard identification which we have already seen in the earlier lectures let us quickly revisit this again and understand hazid. Hazid is useful in identifying the initiating events. It is done through a broad review of possible hazards present in the system, and also identifying the sources of accidents.

So most of the job of QRA is done at hazid stage itself, and then in that case you lead to identifying the critical hazards and then classifying them based on the severity of consequences. What is the advantage of classifying them? Once we classify them you will know what should be the decision on level of analysis. Some of the hazard identification tools can be listed.

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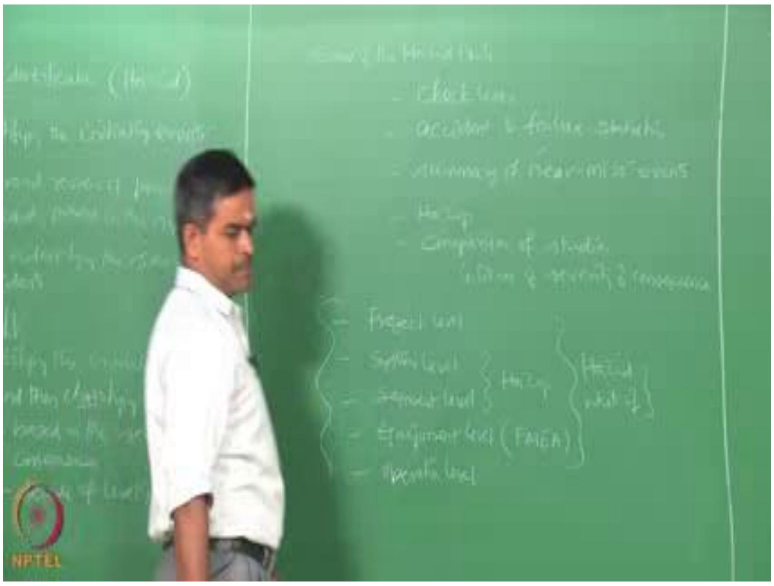

Some of the hazid tools could be; check list, accident and failure statistics, summary of near miss events, hazop, comparison of studies in terms of severity of consequences which can be then applied to project level, system level, segment level, equipment level. If I recollect interestingly FMEA could be useful to an equipment level. If we recollect interestingly hazop could be a useful tool. If we recollect interestingly hazid or what if etcetera could be useful tool.

So, at different levels we keep on doing them. In fact, even operation levels all.

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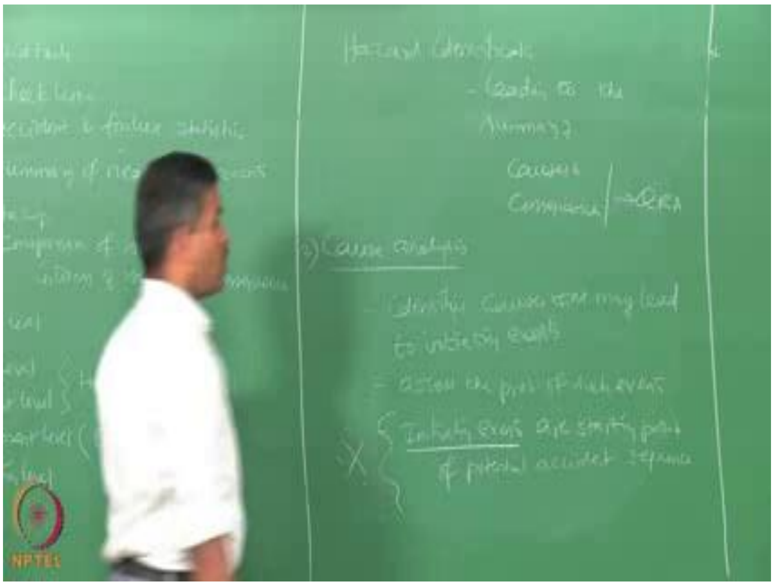

As we agree and understand now that hazard identification is more or less leading to the summary of causes and consequences to take it forward to QRA. Instead of doing hazid analysis one can also do cause consequence analysis. Let us talk about cause analysis. Cause analysis identifies the causes alone that may lead to initiating events. It asses the probability of such events, such events mean the initiative events. We all agree that it is important to identify the cause of hazards or initiating events, because they will be actually starting point of potential accident sequence.

So, initiating events are starting point of potential accident sequence now when you start from there it is very very important statement. So, cause analysis helps us to actually identify these initiating events.

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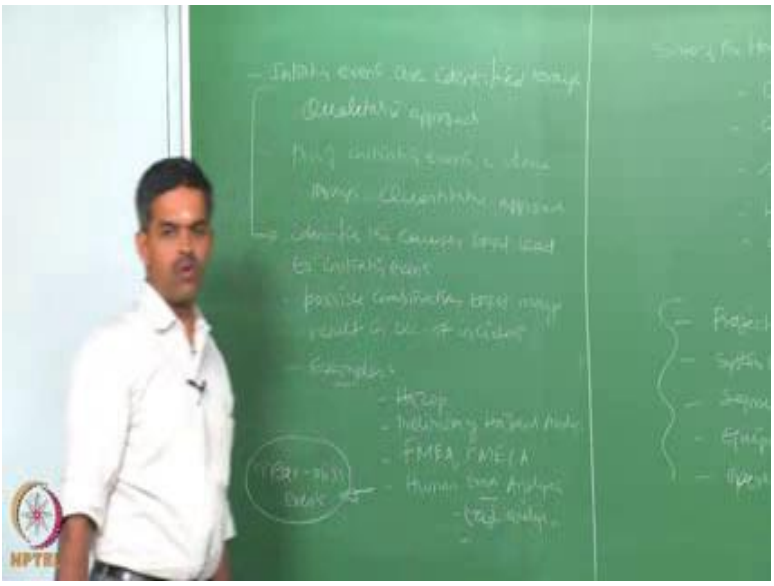

Identifying the initially events is done through a qualitative approach; initiating events are identified through qualitative approach. If I really wanted to find the probability of initiating events then this is done through quantitative approach, identification is through qualitative, probability of occurrence of the initiating event is through quantitative approach.

The qualitative analysis identifies the causes that lead to initiating events. It also identifies the possible combinations that may result in occurrence of incident. Some of the qualitative analysis could be examples which we already studied but still examples could be; hazop, preliminary hazard analysis, failure mode effect analysis, failure mode effect criticality analysis, human error analysis. It is very interesting which will try to tell us what could be the probable over sight which essentially comes from near miss events or reporting of near miss events you will be able to get human error analysis. One can also look at task analysis, one also look at error mode analysis.

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If we look at alternatively the qualitative approach which will lead to estimating probability of occurrence of initiating events, some of the examples could be; fault tree analysis, even tree analysis, synthesis models, Monte Carlo simulation, and one can be also use BORA methodology. Interestingly all are elaborately explained in Srinivasan Chandrasekaran, 2016, Risk and Reliability of Offshore Structures which is CRC process. The reference in terms of ISBN number is available in the reference section of NPTEL website of this course.

Parallely we also have one more course on NPTEL which talks about Risk and Reliability. Please we can do this course. Very brief examples and very interesting definitions of this kind of assessment are also explained in this course. So for parallel understanding and additional reading I would urge and I can go through this lecture nodes from NPTEL which is again free plus the reference to text book which is been authored by me.

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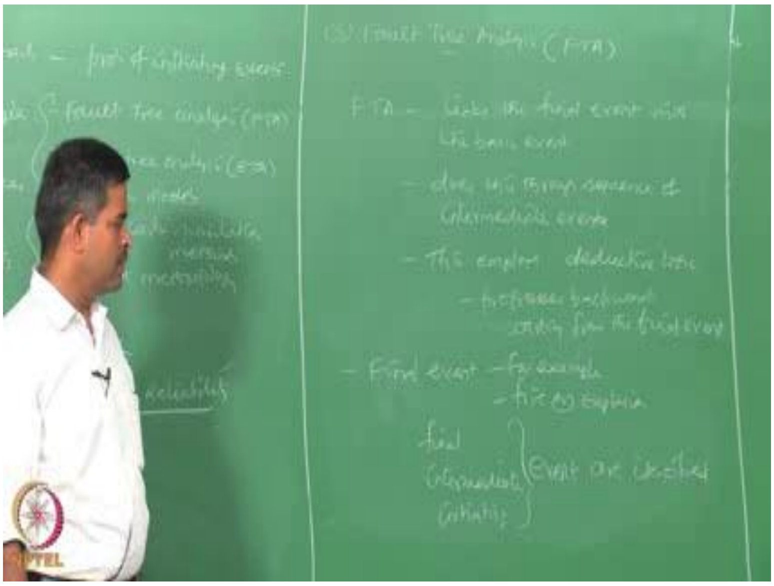

Now let us talk about fault tree analysis, which is one of the quantitative risk assessment methods which are useful in identifying the probability of initiating events which can lead to incidents. Fault tree analysis links the final event with the basic event. It does it with through a sequence of intermediate events. This uses deducive logic, which means that it progresses backwards starting from the final event. The final event may be for example is fire or explosion. Then for that particular event which is the final event, final intermediate and initiative events I identify which are consequently interlinked through different gates.

Let say the basic event.

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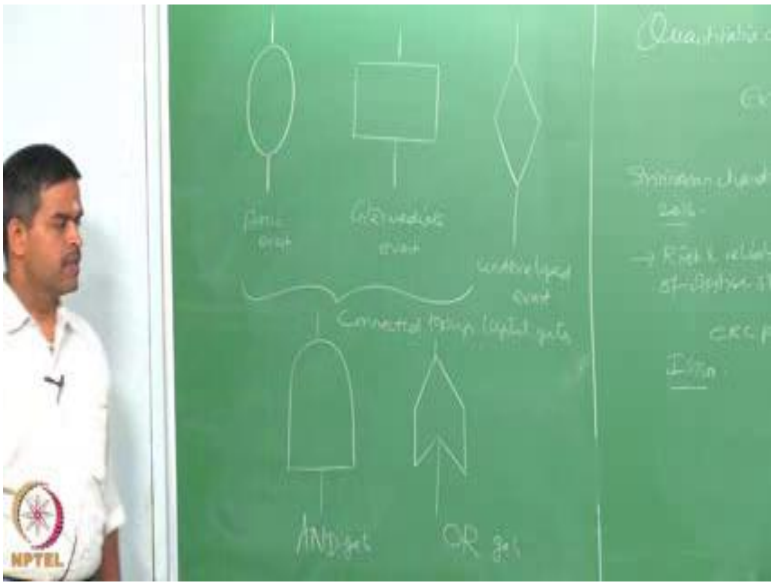

This indicated in this manner, then intermediate event is indicated in this manner, and then undeveloped event is indicated in this manner. These events are generally connected through logical gates. There are two kinds of gates is what we call as; AND gate, is this one is call as OR gate. You know both the case in the logical analysis in building a fault tree really connect these events.

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So therefore, the probability of final event is calculated or is computed using AND gate and OR gates, let us taken an example quickly. We need to construct a fault tree for the formation of fireball. Let say the final event which we identified is a fireball. When this can occur then the chances of liquid petroleum gas is released from a pressurized vessel then this can occur. The reasons are the chances or the reasons of release of this particular gas could be; weld failure, can also be opening of relief valve, by the operator by mistake etcetera.

So, one can look into the detail possible causes in a chemical manner of occurrence of fireball from the LPG gas release looking at David and John, 2007, Marco Pantiggia et al 2011. For more understanding of chemical phenomena of formation of fireball from that of LPG release from contain pressurized vessel. Because of the chances are reasons of weld failure or opening of relief valve when the LPG gas released from a pressurized vessel which could result in a fireball as a final event.

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The flammable mixture which is form now will get ignited if there is a regression source. Once it is ignited, it becomes a fireball. All these events put together can be demonstrate easily using a fault tree analysis. So, please pay attention to the figure shown on the screen now.

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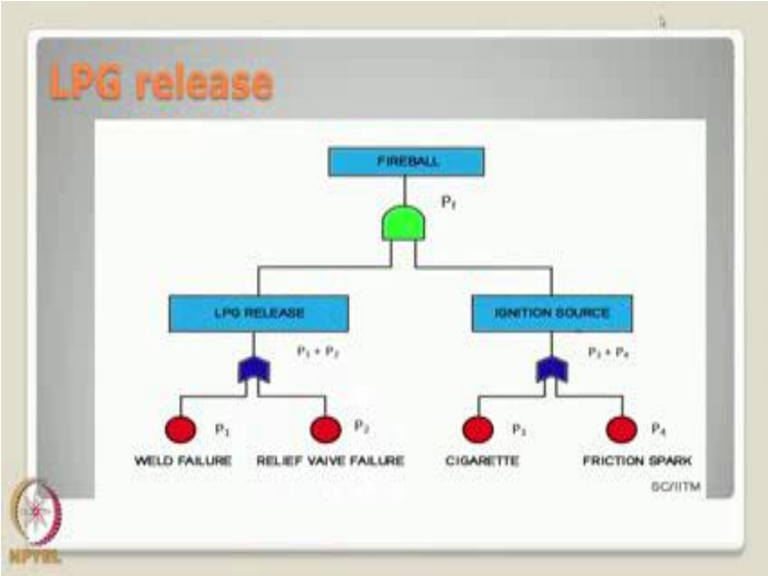

Let say the final event is the fireball looking backwards. We have different kinds of gates as you seen green and blue color, different kinds of gates AND gate and OR gate. The reasons could be to estimate the probability of failure of fireball we could have a LPG release and ignition source both present then only one can have a fireball. LPG release can occur either due to weld failure or due to relief valve failure.

So, the probability of weld failure in a given system is let say P 1 and the probability of relief valve failure in a given system which can lead to LPG release could be P 2, so LPG release can have a possibility of P 1 plus P 2 as a failure probability. Similarly, ignition source can be either from a cigarette or a smoking zone or from a friction spark which can also occur from mechanical aberrations of different systems are moving of cranes objects etcetera. So, the probability each one of them is taken as P 3 and P 4 ultimately one is interested to know what is the probability of occurrence of fireball provided the LPG release probabilities and the ignitions possibilities of a system are known to me.

Let say probability of LPG release is P 1 plus P 2, probability of ignition P 3 plus P 4, and one can say the probability of fireball occurrence is the probability of LPG release multiplied by the probability of ignition source. You can easily get the probability of fireball is a simpler example demonstrated here. The next study which is also interesting is an event tree analysis.

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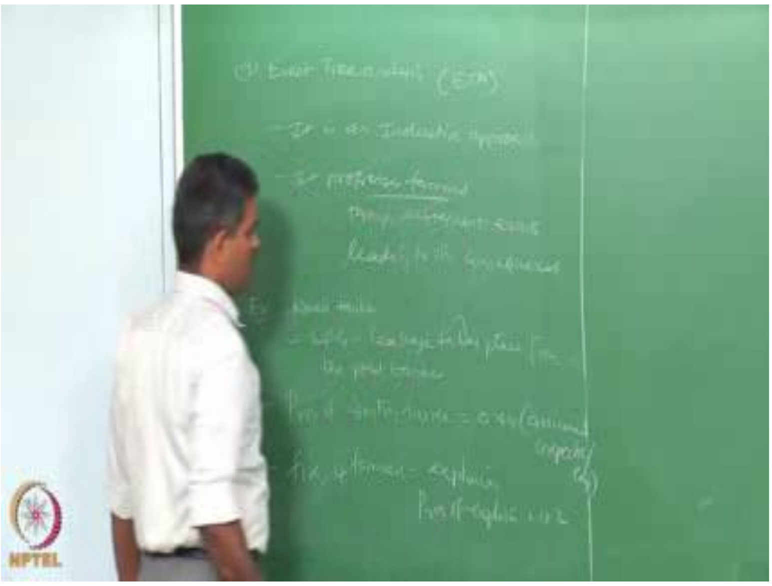

Event tree analysis is an inductive approach, whereas fault tree was deducive approach. It progresses forward, whereas fault tree was progressing backward. It progresses through subsequent events leading to the consequences. One can also illustrate ETA through an example of a leakage of LPG from a road tanker.

Let us say there is the road tanker, LPG gas leakage takes place from the road tanker. Let say the probability of encountering an ignition source is 0.45 which is assumed. Basically it is assumed based on inspection and experience. A fire, if form could transmit to an explosion. Fire, if form could become an explosion let say that probability of becoming an explosion is only 0.2. So, let us construct the event tree for this. Please pay attention to the event tree constructed and shown on the screen now.

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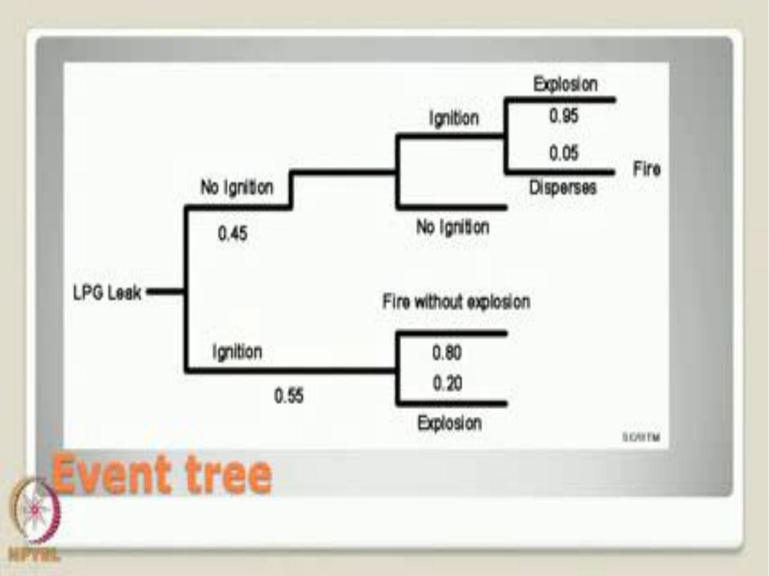

Let say LPG leak is what we looking at. There can be possibility of no ignition source and ignition source. In case of no ignition source it cannot lead to explosion, in that case then the issues are explosion and dispersion which can be 0.95 and 0.05 if there is a possibility of ignition. In case of ignition present then in that case fire without explosion can be 0.8 and 0.2; this explosion is 0.2 and without explosion is 0.8. So, one can lead to fire in case that explosion is for certain one can have fire with explosion one can have fire without explosion.

So, one can easily find out the arrangement of events in different formats laid them connected and try to find out what is the probability of the n product which is nothing but fire with explosion or fire without explosion, the initiating event could be a road tanker leakage. It means these progresses forward from the event identified and takes it to identify the probability of failure of the consequence, whereas in the earlier case is started from the end event and progressed backwards that is the difference.

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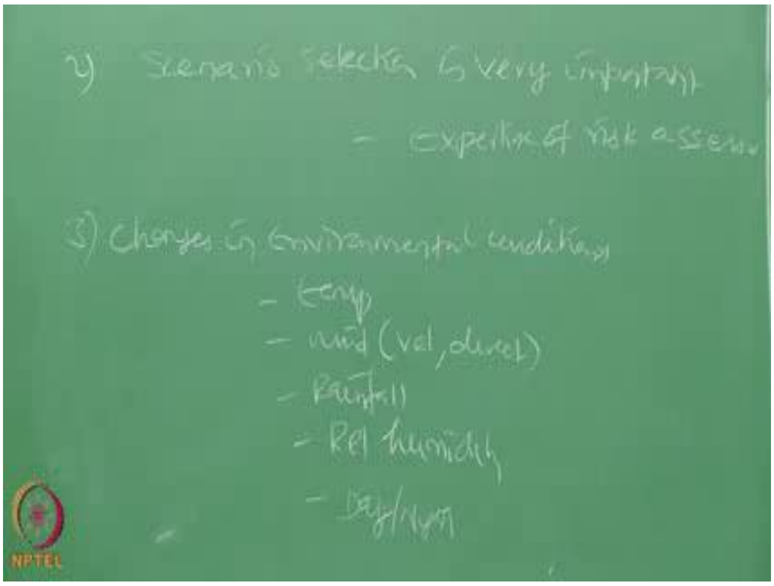

When you look at QRA methods in general there are many disadvantages. Let see what the disadvantages are; different approaches in QRA give different results. So, it depends upon what to be trusted. Scenario selection is very important, as just now we saw in the last lecture. Scenario selection is very important to have an accurate result and it depends on expertise of the risk assessment. Changes in environmental condition also play a very important role in risk assessment in QRA. For example; temperature, wind, both velocity and direction, rainfall, relative humidity, day or night, etcetera. Each software which is used for simulating failure models may give different results for a same scenario.

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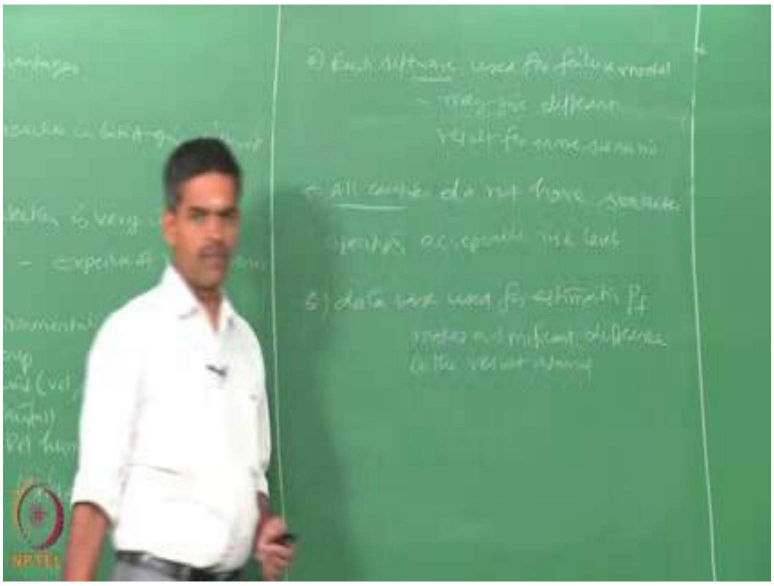

So, it all depends upon how you handle the uncertainty in the software or in the failure models. Interestingly, all countries do not have statutes specifying acceptable risk levels. So, data base used for estimating the probability of failure of any specific event makes a very significant difference in the result.

As we said, when I talk about assessment then you should say what the acceptance is.

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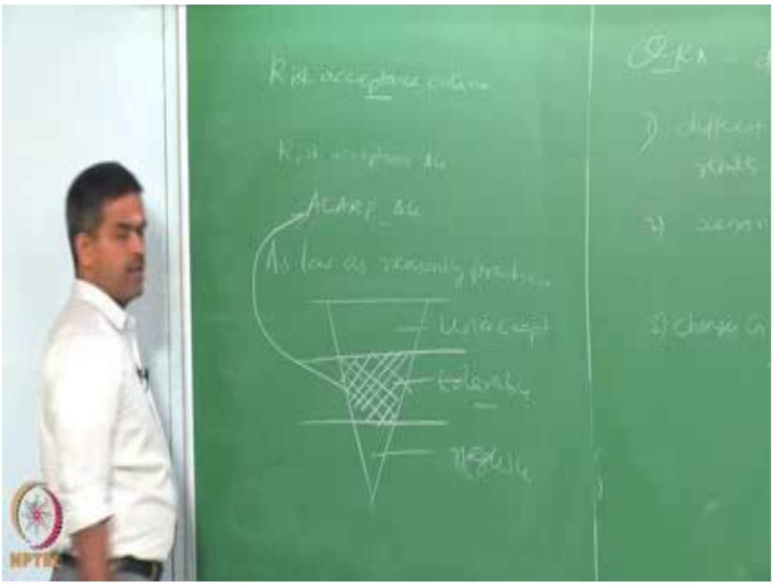

So, if you look at the risk acceptance criteria which are very important to compare the calculated risk from QRA study of the plant with that of the acceptable limits, different countries for a different acceptable standards and criteria for process industries.

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Authority and application	Maximum tolerable risk (per year)	Negligible risk (per year)
VROM, The Netherlands (New)	1E-6	1E-8
VROM, The Netherlands (Existing)	1E-5	1E-8
HSE, UK (existing hazardous industry)	1E-4	1E-6
HSE, UK (nuclear power station)	1E-5	1E-6

Interestingly I show you brief summary of the table please pay attention to the risk criteria in various countries as compiled by IS15656:2006. Look at the authority and application VROM the new one the proposed one and the existing one; HSE, UK and HSE, UK exclusively for nuclear power stations and nuclear industries. The maximum tolerable risk per year is changed depending upon the standards what the country follow. The negligible risk or the risk identified is negligible per year is also identified here.

So, one may ask a question how these two numbers are different for me in defining risk acceptance criteria. To talk about risk assessment criteria let us talk about then the risk acceptance triangle what we call ALARP triangle. One can see here in ALARP triangle as shown in the screen now.

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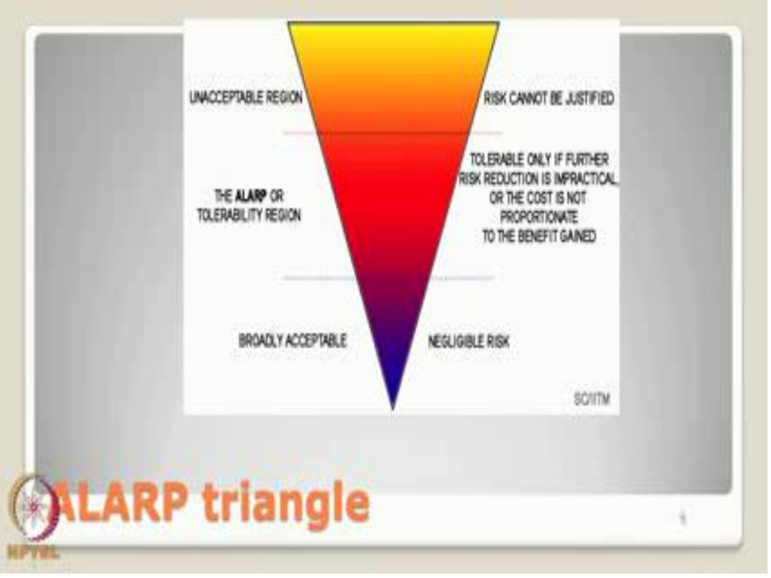

It contains three regions; the bottom one is what we call broadly acceptable region where the risk is highly negligible, the top one is call unacceptable region where the risk cannot be justified at all, the middle region is a ALARP or tolerable region where tolerable only if further risk reduction is impractical or the cost is not proportionate to the benefit gained.

So, friends it is very important to fix of these boundaries. These boundaries are nothing but the values what you see in the screen here, which are given by maximum tolerable risk and negligible risk. Let us see this particular content in the screen back here. This is going to be my boundary for maximum tolerable risk beyond which the risk becomes unacceptable. This is going to be a boundary below which the risk is negligible. So, this boundary lines are given by different standards of international agencies which are followed by different countries. So this region is the acceptable or tolerable region what we call as ALARP, where ALARP stands for As Low As Reasonably Practical.

So, you got three layers; this is negligible, this is unacceptable and this is tolerable let us put it as taller. This boundary and this boundary which fixes by tolerable region or acceptable risk region is what we call as ALARP region which is defined by difference countries by different international standards as you saw in the table just there.

Therefore, friends the line which divides the risk into broadly acceptable and broadly tolerable or broadly unacceptable, varies from different standards and practices in different countries. Therefore, one cannot really quantify risk in sense whether the risk is really acceptable or tolerable depending upon what kind of practice you are following. And interestingly many countries even do not have these standards to be followed; therefore they follow or adopt international standards at different countries. Therefore, there is again a big guess, a big anomaly in fixing these borders of acceptable region or tolerable region of risk.

Of course let us please agree and understand for an offshore industry the statutes of interest and regulations prefix these values. One cannot keep on changing these limits as and when the industries being formulated, these standards are prefixed. However, on what basis they are prefixed can there be alter, can they be revisited it all depends on the country statutes or what practices do they follow in respective countries.

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The maximum acceptable risk in offshore process industry downstream sector is 1 into 10 power minus 4 per year, that is the maximum limit. Above this value risk becomes unacceptable. Therefore, in between is the ALARP region we show that risk is tolerable only if further risk reduction becomes either in practical or the cost involved in risk reduction is not proportionate to the benefit gain because of risk reduction; that is the ALARP triangle.

So, friends in this lecture we understood about the application issues on QRA. We have also understood what are the important data are require to do qualitative and quantitative risk assessment methods, we have seen some examples. We have also understood how to construct a fault tree and event tree in simple form for identifying a specific fault or a specific probability of failure in a given system. And we also see in the summary at the end what are that issue which makes actually risk manageable or acceptable provided to estimate at risk using QRA techniques.

However, whatever estimate you make from QRA techniques which has got certain uncertainties, certain difficulties in terms of methods by which you are a employee and country what you are following or practices what you follow, the acceptability of risk what we deduce from the models is depend upon what is the statutes you are adopting or what practices you are following in your country.

So, it is very interesting that we do not have a global single standard of acceptance of risk which can be applied to all countries and all process industries because it is all depend upon the economic index of the specific country, the process of style of manufacturing, and the product cost, the taxes, the public interest, etcetera.

Therefore, this is a very large embrace to understand risk definition in terms of global standards, but certainly we have to agree the standards have been formulated and industries are following them stringently so that we are all the time aiming to manage and reduce risk and we have to agree at a final statement that offshore industry in terms of process industry is not a zero risk industry. Because of high degree of uncertainties involved in the whole process you cannot actually make risk as practically zero, you design them to become zero but however because of environmental conditions, because of operational variations risk will be envisaged and risk will be present.

So, what we have got to look at is the risk available or projected or probably identified is within the acceptable limits or not. If not, we should manage risk so that bring it to the acceptable level. If it is already in the acceptable level let us try to maintain that levels so they does not go to an unacceptable standards.

Thank you very much.