Health, Safety and Environment Management in Petroleum and offshore Engineering

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Module No.#03

Lecture No. #05

Quantitative risk assessment

Now, we will talk about fifth lecture on module three, which is on quantitative risk assessment. In the last two lectures, we discussed about chemical exposure index method. We discussed couple of problems to know, how to do a chemical risk analysis for gas and vapor release models.

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Today,we will discuss about something on liquid release models in detail.We will talk about liquid release models today, before that, let us quickly summarize once again for our own interest, world disasters which occurred in oil industry. We have already discussed many case studies in the first module, just for the interest we will summarize once against them.

Oil tanker Torrey Canyon grounded in English Channel1967, U.K. production platform piper alphadisaster occurred in 1967. The Capsize of the Norwegian accommodation platform AlexanderKielland in occurred in 1980, the Exxon Valdez oil spill occurred in 1989. The pipeline ruptures in Usinsk area, Russia occurred in 1994. Buncefield fire occurred in 11 December 2005 at Hertfordshire are oil storage terminal, and Gulf of Mexico BP oil disaster which occurred in 2010.

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We have already understood, the necessity for revising these kind of accident scenarios occurred in oil industry. Let us quickly revise what do we mean by the necessity for safety. High growth in industrialization in the last few decades resulted in numerous problems with handling and use of hydrocarbons. Major accidents represent the ultimate,most disastrous way in which a petroleum industry projects can go wrong. Accidents cause death, suffering and pollution of the environment and disruption of business. To minimize these accidents risk evaluation of various installations are actually required to be carried out.

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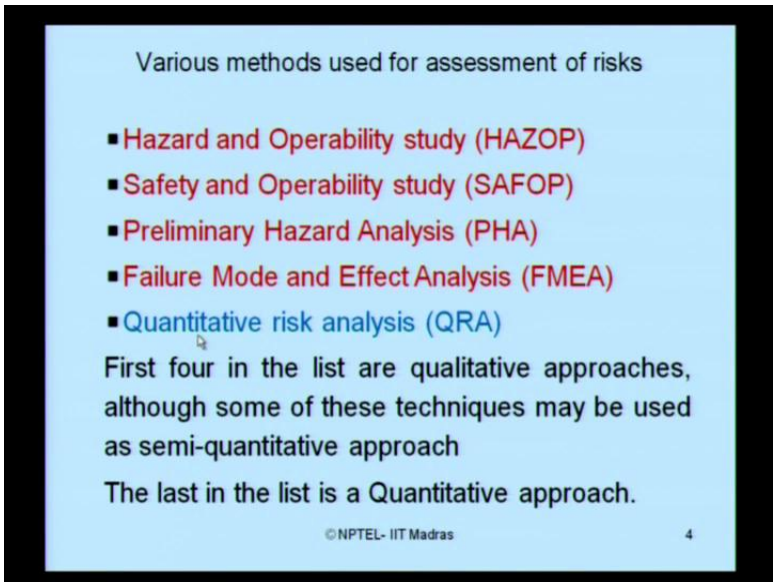

There are various methods which are employed in risk assessment. Some of them we have already seen, just for summarizing for interest. One such method is what we call as hazard and operability study, the second method is safety and operability study, the other method is preliminary hazard analysis, the fourth method is failure mode effect analysis, and the fifth method is quantitative risk analysis.

There are some commonness in these first four methods which is different from the fifth method. The firstfour methods in the list are actually qualitative risk analysis, because they have some qualitative approaches in their modeling. Some of them also have some semi quantitative approach, but the last one is purely quantitative risk analysis method, which is also employed for assessment of risks. In this lecture, today we will discuss about the liquid release model based on quantitative risk analysis.

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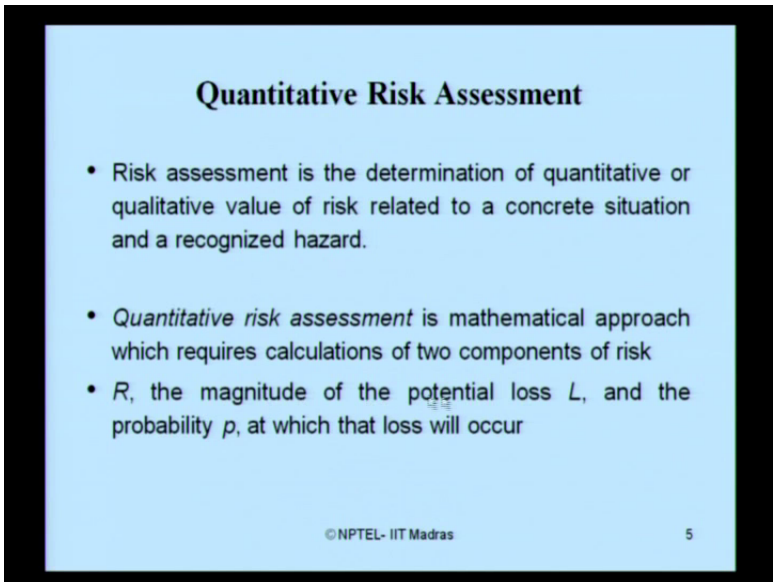

Now, make you to understand, what is quantitative risk assessment? Let us briefly give you some statements. Risk assessment actually is determination of quantitative or qualitative value of risk which is related to a concrete situation and a recognized hazard. Remember hazard is a scenario risk is a realization of that scenario that is why, we say risk related to a concrete situationand a recognized hazard. Quantitative risk assessment which is famously address literatures QRA is a mathematical approach which requires calculation of two major components of risk. Ladies and gentlemen, can you recollect these two components of risk, which are very important, you are right. One is what we call as magnitude of the loss, another is the probability at which this loss will occur.

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If you look at the QRA method, let us quickly ask a question to ourselves what do you understand by objectives of QRA?Estimating the risk levels and assessing their significance. Identifying the main contributors to the risk, defining design accident scenarios,comparing the design options, evaluating risk reduction measures,demonstrating acceptability to regulators and the workforce, identifying safety-critical procedures and equipment, identifying accidents precursors and soon.

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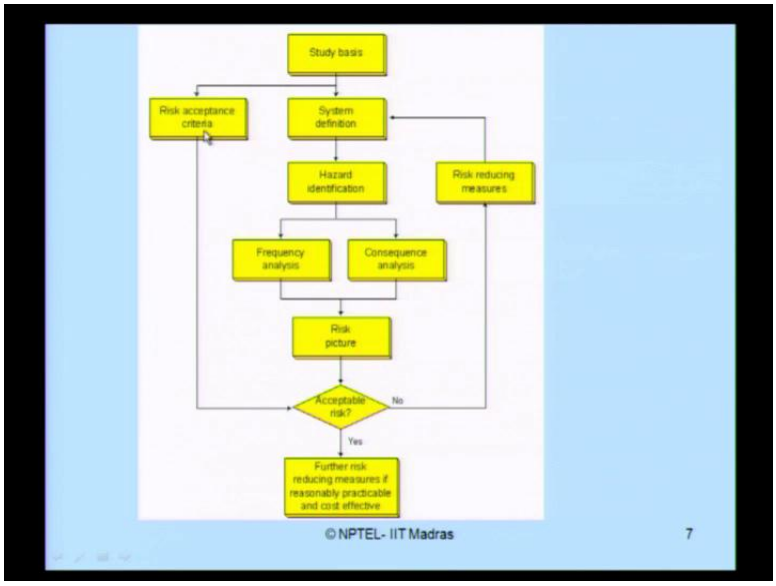

Let us quickly look at the flow chart of QRA.Let us say, I would like to see on what basis the study is to be established. What we call as a study basis, you have a problem,you wanted to do your quantitative risk assessment for the problem.First of all, let us establish a basis for that study. Once you established the basis for the study, you try to look at the risk acceptance criteria for that problem.

Ladies and gentlemen, we all understand that the risk acceptance criteria vary for different problems. So, identify the risk acceptablefor the case study which you are discussing. If that level of risk is acceptable to you then further carry out risk reducing measures if reasonably practical and they are cost effective. If the risk assessment criteria or acceptance criteria is not acceptable for you, then the question comes, how do you do a QRA?How do you actually do the risk assessment using quantitative tools?

To do that, the first step would be define the system. First from the case study, identify the case study and then start defining their system, what we call as system definition. For the defined system, identify the hazards, once you identify the hazards, calculate the frequency of occurrences of that parameters, and if at all theyoccur what would be the consequence of that occurrence in the industry.Based on these two quantitative values, calculate what we call as risk picture. Once the risk picture is known to you for a specific case based on the system definition, see whether that risk is acceptable to you. If I say you, I mean to say the management because acceptable level of risk is a subjective value. The one which is acceptable to you as an individual may not be acceptable to you as an management.So, look at those acceptable levels which are given by international standards, if those risk are not acceptable at all as per the international defined standards then start thinking of risk reducing measures.

Introduce suggest recommend some risk reducing measures againredefine the system for those risk reducing measures in position then again carry out this picture and check whether the acceptability is now reached. If the acceptability is now reached then look for can you do any further risk reducing measures, sothat, that measures can be cost effective and reasonably practical. So, that is how a flow chart can be easily explained for a quantitative risk assessment.

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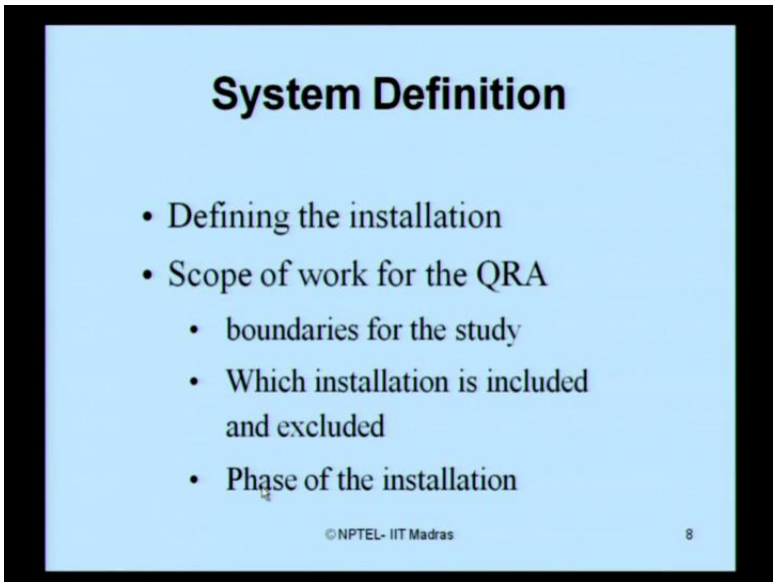

System definition becomes a very important step in QRA. So, what do you do for system definition? First of all define thoroughly the installation, depending upon the case study you are looking for examining QRA define the total installation of the system. Define the scope of work for your risk assessment. In the scope of work look carefully for what are theboundaries of your study. In the total installation of the plant which installation will be included in your study and which you want exclude in your study. Also look for the Phase of installation in the plant.

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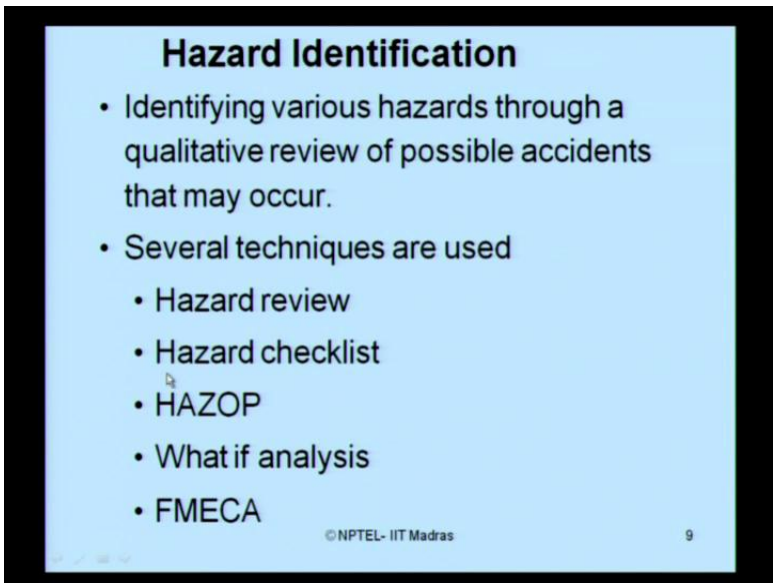

Once, you do that then carry out what we call as hazard identification. Identify different hazards through a qualitative review of possible accidents that may occur. For an identified system look for those possible scenarios of accidents qualitatively review them, what we call as identify various hazard scenarios for the given section of the plant. For this, probably you can use several techniques - hazard review technique, hazard checklist, HAZOP,what if analysis, FMCA, FMEEA,etcetera.

Ladies and gentlemen, you will be happy to recollect that we have discussed at least three of them in detail namely hazard checklist, HAZOP problems and FMEA thoroughly before we come to this module.

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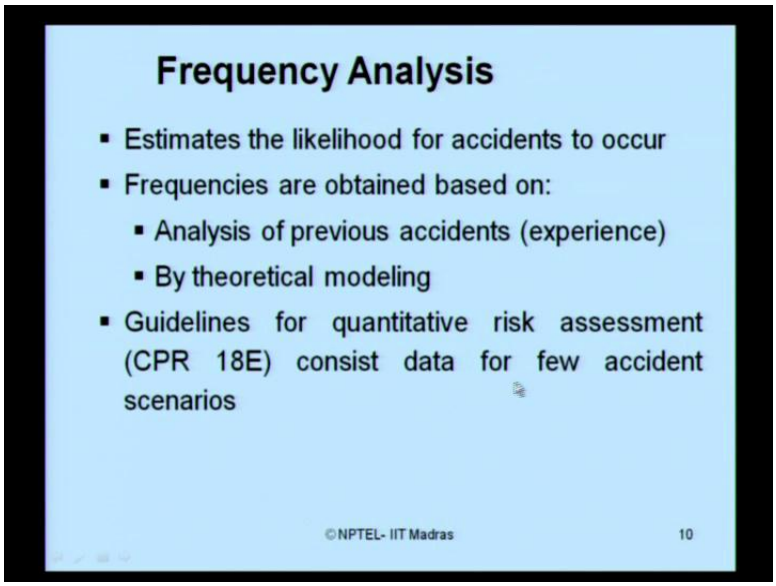

Let us look, at what do we do in frequency analysis. Frequency analysis actually estimates the likelihood for accidents to occur. The frequencies are actually obtained based on analysis of previous accidents what, we call as expertise or experience or otherwise by theoretical modeling. There are some guidelines available for doing this kind of accidents scenarios CPR 18E is a reference book which contains data related to past few accidentsscenarios.

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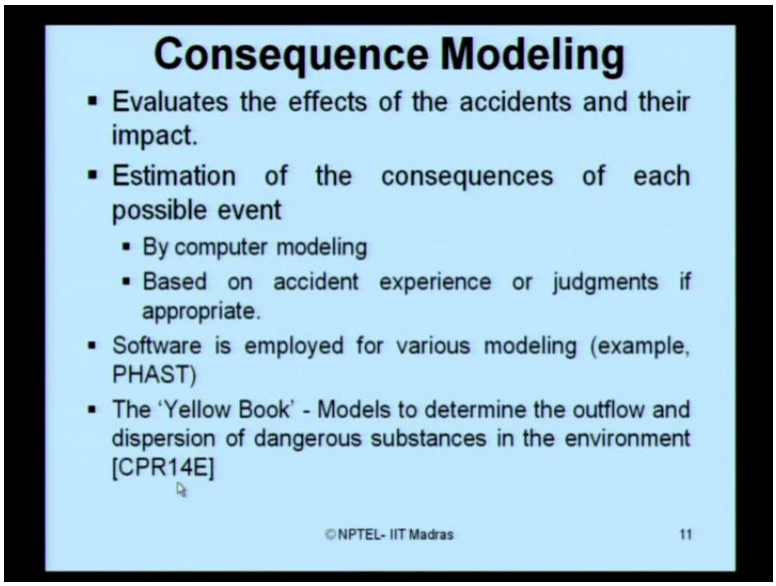

Then subsequently you do what is call consequence modeling. This evaluates the effects of accidents and their impact. The estimation of the consequences of each possible event as to be done, this can be done either by a computer modeling or based on accident experience or based on judgments if they are appropriate for the chosen problem.We are actually interested in evaluating the effects of these accidents and their impact on the plant. The moment I say effects and impact, you can very well understand, we are not focusing only on the impact to human health, we are looking on different aspects of impact of accidents including the financial loss, including the environmental effect, including the societal risk, all we have discussed in module one.

Can you, look at those lectures once again, just review back what do you mean by impact of any specific accident on the public scenario. So, once you understand the effects of accidents and their impact, estimate this consequences based on software.We will discuss that in the subsequent modules and lectures based on some accident experience or judgment if you already have and if you feel there appropriate for the selected problem.

As a example, software can be also be used for doing consequence modeling. There is the software by dnb which is called PHAST. This can be employed comfortably to do what, we called as consequence modeling.Alternatively you can also look for yellow book, this has certain models to determine the outflow and dispersion of dangerous substances in the environment which is given as CPR14E guideline.

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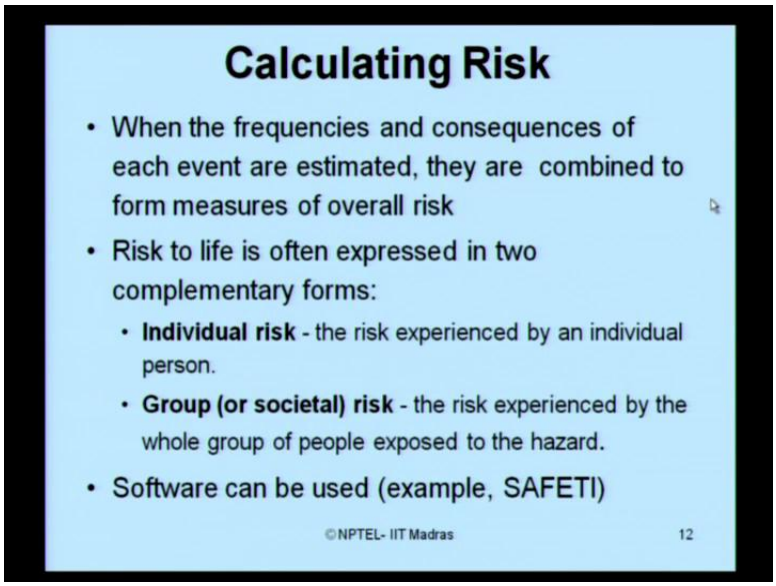

We can, also look at this reference manual for modeling the dispersion problems. Once, you understand the consequence and the frequency, now try to estimate what we call as risk. Compute the risk, risk is nothing but the product of these two, when the frequency and the consequence of each event are estimated then they are combined to form the measures of an overall risk. So, risk is nothing but the product of frequency of occurrence of any specific event identified and the consequence of that even if at all the event occurs. Risk to life is often expressed in two complementary forms, we have already seen them in detail with equations available for different international standards.

Just for completion say, I also wished to put that definition back once again in a very comprehensive form. Riskto life can be done in two formats - one is what we called as individual risk, other is what we call as group risk on societal risk. Individual risk is that risk experienced by an individual person,whereas, society risk is that risk experienced by the whole group of people exposed to that hazard level. You can also use software to estimate the risk,for example, SAFETI is one software which can be used for estimating risk, once you have the frequency and consequence of the events identified by you.

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Once, you have the risk picture in front of you, we can talk about what we call as risk reduction. Can I really reduce the risk? Now the question comes when do I look for risk reduction? Can you answer this question exactly? What you are thinking in mind is correct, first of all the estimated risk or the evaluated risk is checkedwhether it is within the acceptable limits or not. What we call as acceptable risk level, once a risk level is within the acceptable level then there is no point in applying risk reduction at all.

If at all the risk estimate is beyond the acceptable level which is defined by an international standards and regulatory measures, remember acceptance criteria of a risk is a subjective value,therefore, you need a regulatory measure to basically define what kind of risk you are going to accept for your problem. So, once that estimated risk crosses the accepted level of risk for your problem then the question comes the necessity for risk reduction. So, you should make recommendation in your analysis, to bring down the risk to the acceptable level. Then the benefits can also be evaluatedby repeating the above process within cooperation of the reduction measures.You also try to work out the economic benefits of the measures and compare them with the risk benefits using what we call as cost benefit analysis.

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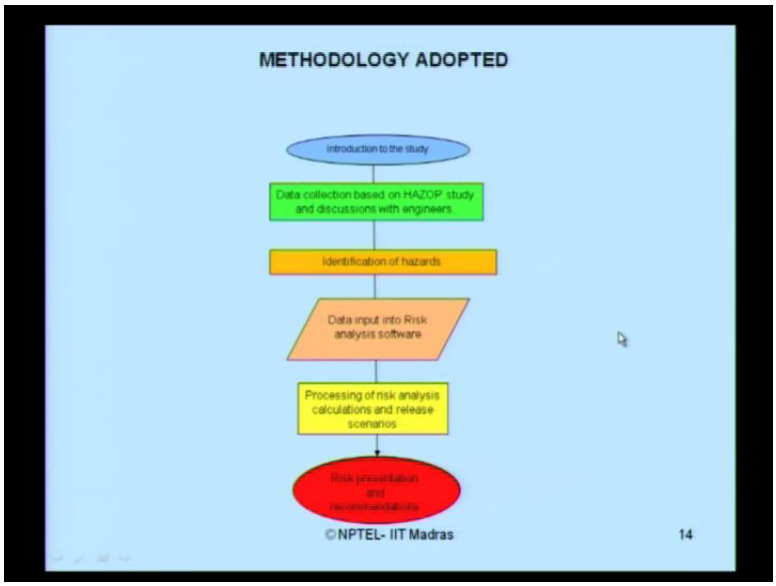

I can also give a very brief flow chart for the methodology which is generally adopted for a QRA.First try to identify the case study, introduce the case study in detail to yourself, try to collect all possible data required based on the HAZOP study and then discussion with the engineers. On the other hand, if you want to really do a quantitative risk analysis successfully, first we must conduct an HAZOP study and try to collect all data based on this HAZOP study.

Based on the HAZOP study conducted, try to identify the hazards present inthat specific case study. Try to see the data required to input for risk analysis software. So, this very clearly tells you that, you should be aware of using any standard software which does risk analysis. So, look at the software learned the basic tools available in the software, see in what format the data is requested in the software and try to see what input actually you need to use the specific risk analysis software. Once ,you get the results as an output from the risk analysis software process the risk analysis calculation and then the released scenarios.

Based on the released scenarios, make what we call as risk presentation which will be nothing but an hazard curve or a risk presentation curve. We will prepare an output in a graphical format and based on that level of risk evaluated from your case studycheck whether they are within the acceptable standards of the company or the regulatory measures then give subsequent recommendations to reduce a risk to the acceptable

standards. Ladies and gentlemen, it is the very, very simple flow sheet to do what we call as QRA.

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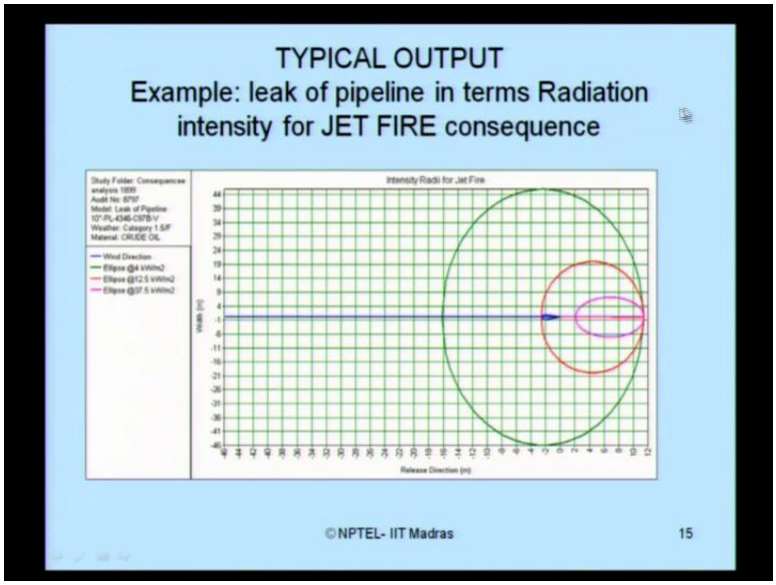

I can give a very typical example of a typical output what you get from software. If you do a QRA,this example shows an output of a QRA study conducted, for a leak of a pipe line in terms of radiation intensity for a jet fire consequence. Look at this curve, this is expressed in graphical format, the release direction in terms of meters is being given and then the width of the spread in terms of meters is been given.

This is actually a data sheet which we have been using for analyzing aleak of a pipeline. The weather condition is considered, the material leaking is basically a crude oil, and you can see here is the wind direction. Then there are three ellipses you get - one is a crayon, one is a red color, other is a green color.Of course, you can change this color depending upon your requirement or protocol of the company. So, what we want to emphasis here is very simple, the ellipse area tells me that the radiation intensity in this segment is about 37.5 kilowatt per square meter,whereasin the green segment and the red segment subsequently they are 4 kilowatt per square meter and 12.5 kilowatt meters respectively.

So, what you get from QRA using software is a typical output of this kind graphically, you will alsoget an output on literally means which will discuss in a specific case study subsequent to this lecture.

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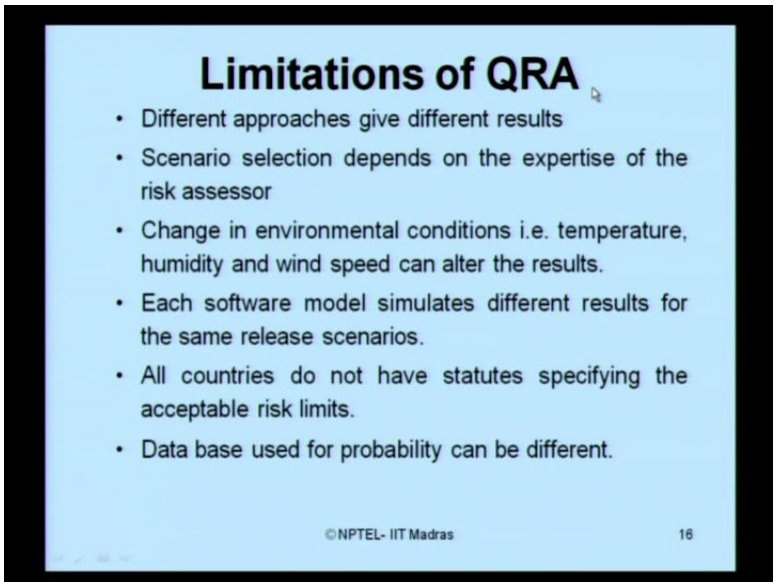

There are, obviously, some limitations on QRA studies before we perform actually a QRA for a case study which will be quite interesting for you to learn, let us clearly accept the limitations of this study. Now unfortunately different approaches give you different results. The scenario selection depends on the expertise you have on the specific problem. The change in environmental conditions,for example, the operating temperature or the ambient temperature during the released of the liquid or a gas, the humidity conditions present at that stage or state of release, and of course, the wind direction and speed can subsequently alter the computers resultswhich you have estimated from your QRA studies.

Each software model simulates different results for the same release scenarios. This is very interesting for you to know that there is no unique answer what you will get for a release scenario. If you use different software models, though there are some commonness, there are some common results which will get from almost all software, but there is no guarantee that each and every software model will simulate the same kind of result which is going to be common through and through for all software models, that is not true.

And unfortunately, the acceptable risk limits vary widely for different countries. So, we put it the other way all countries do not have statutes specifying the acceptable risk limits. It is a very carefulsentence, there are many countries which even do not define an

acceptable risk level at all for a petroleum company. The data base which you use for the probability estimates can be subjective and can be different as well. So, these parameters will strongly influence the results what you obtained from your study conducted on QRA,what we put them as limitations of QRA.

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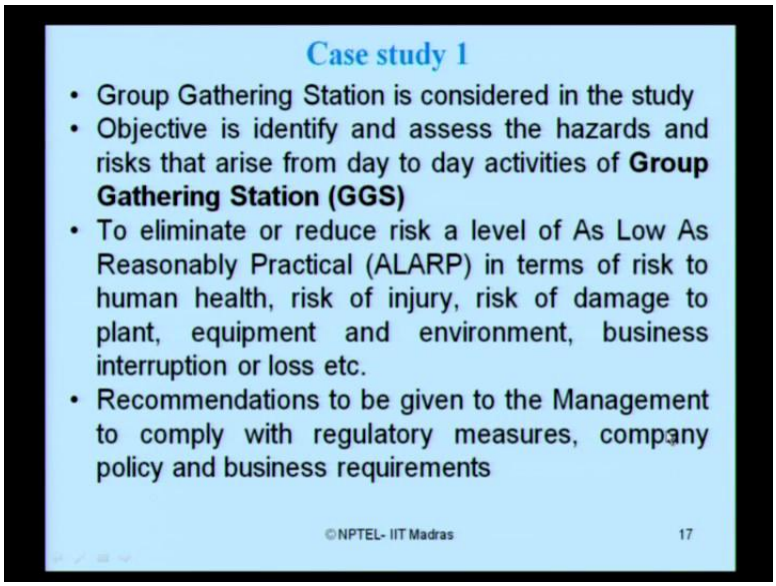

We will, discuss one specific case study of quantitative risk assessment now. The case study, what I am going to examine is nothing but the group gathering station. You can recollect that we have already done on HAZOP study for a group gathering station which we discussed in detail in module one lectures. I have looking the same example again, now I am going to performa different mode of study, the HAZOP study what I conducted for a group gathering station case was a qualitative analysis.Now, I pick up the same example and demonstrate to you how can Ido a quantitative risk analysis for that.

So, I am picking up the same example actually. The objective is to actually identify and assess the hazards and then subsequently the risks that arise from daily activity of what we call as a GGS. I am actually interested to eliminate or to reduce the risk to a level as low as reasonably practical, what we call as ALARP level. In terms of risk to human health, risk of injury, risk of damage to the plant, equipment and environment, business interruption or loss etcetera.

So, ladies and gentlemen please understand that, the risk is not only relatedto human health. It includes injury not a fatal, it includes damage to the plant also which is the

capital loss, it includes damage to the equipments which is again a capital loss,it includes risk to the environmental which is again a legal issue. Also any business interruption created due to the risk is also considered as a loss. So, when I say risk assessment, I am analyzing or I am assessing overall in a very broad scenario of many things, it is not only human health.

Then subsequently I must give recommendations to the management to comply with regulatory measures, and the company policy and the business requirements. So, the outcome of any case study which we will discuss as QRA should result in list of summary which I say as recommendation to the management, and those recommendations cannot be very, verysubjective or very funny. They should be complying with the regulatory measures, international standards and also they should strongly follow the company policy.

Remember that any risk mitigation or reduction is always initiated with the willingness from the company or the management. To every company has a business policy, you must always appreciate and respect the business policy of the company, business requirements of the company then accordingly chalk out the recommendation in your QRA study.

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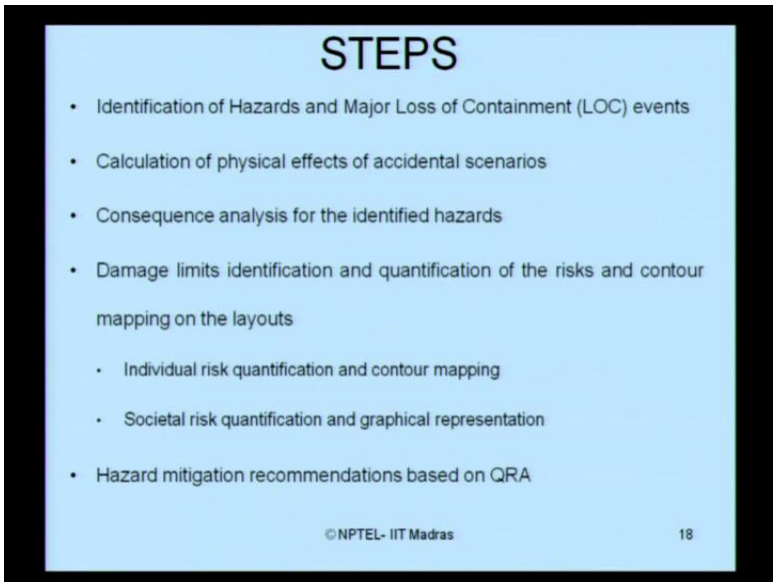

What are the steps involved in the QRA study. The first step, obviously, is identification of hazards and the major loss of containment events what I call as LOC. In a given

problem, I tried to identify what is the major loss of containment and what are those events responsible for this kind of loss, and also identify the hazardsrelated to that scenario. Then calculation of physical effects of accidental scenarios, consequence analysis for the identified hazards, then damage limits identification and quantification of the risk in terms of frequency, and then contour mapping on the layouts.

I will also look at independent to individual risk quantification and the societal risk quantification which I am trying to explain in terms of graphical representation. All software, ladies and gentlemen, in general give the output of risk quantification in terms of graphical representation. And ultimately the hazard mitigation recommendations based on the QRA what you study. As I clearly emphasis, the recommendations what you make as a QRA analyst should comply to international regulations and of course, you should respect the company business policieson which you are employing this studies. Remember this statement, this is very, very important; otherwise your recommendation will go in vain, because risk mitigation or reduction actually is a willingness process from the company.

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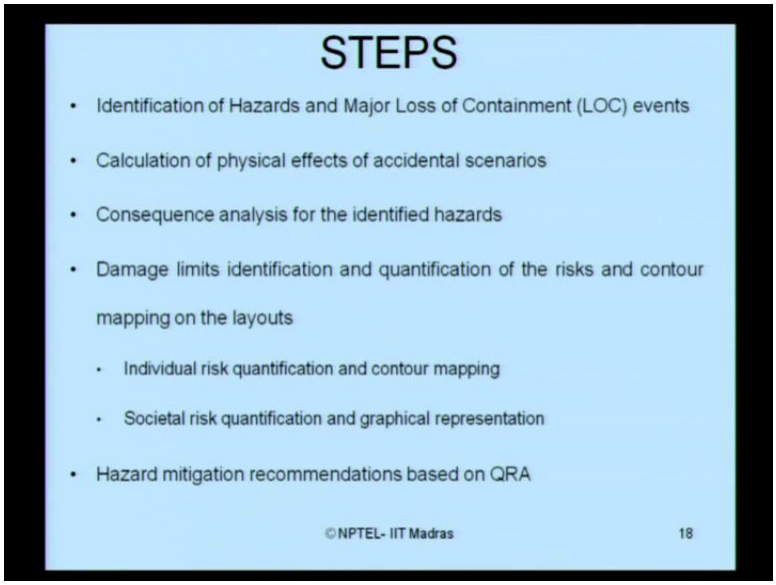

Now, you have some preliminary requirements to carry out the study. Let us quickly see, what are those requirements. You must have what, we call piping and instrumentation diagram, which I call as P and ID. This P and IDs should indicate clearly, the design and operating conditions. Then I must have what is called process flow diagram which

briefly I call as PFD. Then I must understand completely and thoroughly the operational and control philosophy involved in the segment of the plant.

I must have a complete layout drawing, which is thoroughly drawn to scale formy problem. I should also have the complete details of the fire detection systems and the protection facilities available in the near vicinity of the plant. Remember that we are not only focusing on the risk reduction measures available in the plant itself, but also in addition we looking for those protection facilities available in the near vicinity of the population as well. And also try to find out all details available on emergency shutdown system if applicable to your study. And very interestingly, you must have the details of population the density of population, in the vicinity of the problem, where your plant is situated.

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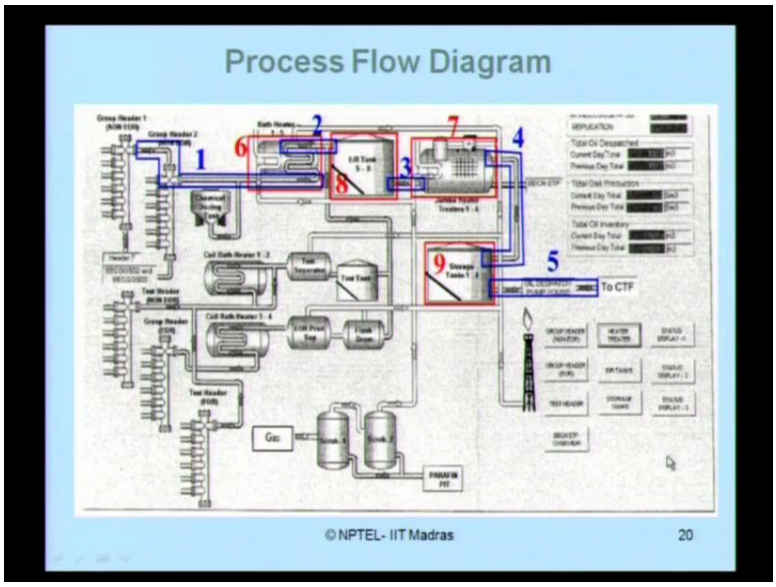

Now, I have a similar case study with me. This figure is as same as what, you saw in one of the lectures on HAZOP study in module one. I am recollecting the same figure once again for the benefit of the viewers. I am having a process fluid diagram now on the screen. Now I have made a small modification in this process flow diagram, I want you only to look at that modification or draw your attention only to that. If you look at this figure very clearly, I have numbered them in a scenario of 1,2,3,4,5, they are in blue color, the other scenario as6,7,8, and 9, which are in red color. Ladies and gentlemen, can you really find out the difference between the numbering 1 to 5 and 6 to 9? Because

they are in different colors, it is very simple. The numbers or the events related to 1 to 5 or something related to the piping or the piping system, the numbers from 6 to 9 are related to the tanks or the vessels, for example, 6 is an assessment on bath heater;7 is an jumbo heater treat,8 on the ER tanks, and 9 on the storage tanks.

So, I am looking QRA on two distinct levels. One is on the pipeline segment of the whole problem, starting from the group header to the CTF. The other is on the vessels or the tanker, where my process is taking place. Is that understood? So, this is going to my base of the process and flow diagram based on which I am going to do a quantitative risk analysis. I have already done a qualitative risk analysis for these, which I addressed as HAZOP in the first module lectures.

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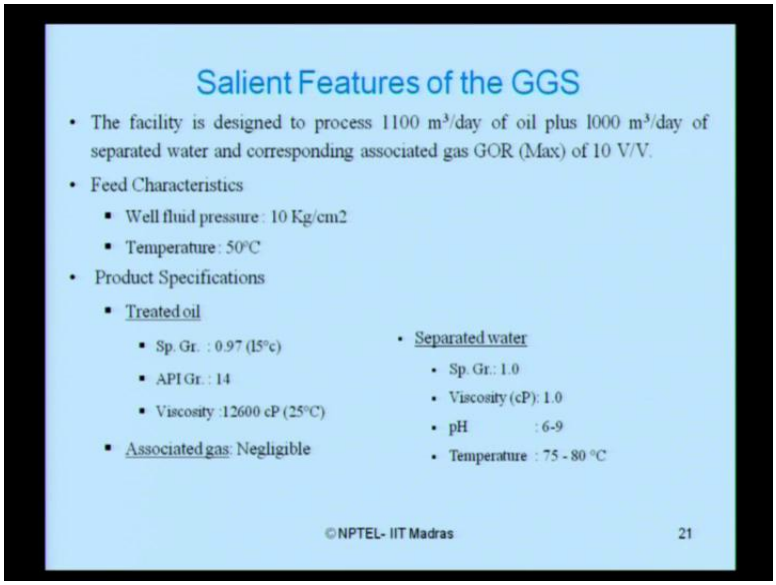

There are some salient features of the GGS. Let us quickly go through that. The facility actually is designed to process 1100 cubic meters a day of oil in addition to that1000 cubic meters a day of a separated water, and the corresponding associated gas - which we called as GOR to a maximum of 10V by V. Now the feed characteristics of this plant are the following: The fluid pressure is about 10 kilogram per centimeter square, and the temperature operation is about 50 degree Celsius. The product specifications are as follows: The treated oil has specific gravity of 0.97 at 15 degree Celsius; the APIgrade is about 14, the viscosity is about 12600cP at about 25 degree Celsius.

The separated water has a specific gravity of 1.0, the viscosity is again one 1.0, the pH level of the water is about 6 to 9 it is basically alkaline, and the temperature is about 75 to 80 degree Celsius. The associated gas in this process is combatively negligible,therefore, I am not focusing on this at all for this specific case study.

So, now you have ladies and gentlemen, the process and flow diagram, you have understood the flow philosophy completely you have understood the salient features of the plant, now we have prepared to do a case study in the next lecture.

Thank you.