NPTEL

NPTEL ONLINE CERTIFICATION COURSE

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

Module 2:
Accident modeling, Risk assessment & Management
Lecture 3: Liquid release models

Friends we will now present to you the third lecture on module 2 where we are going to discuss liquid realize modules under the module 2 of accident modeling risk assessment and management which an online course on HSE at NPTEL IIT Madras.

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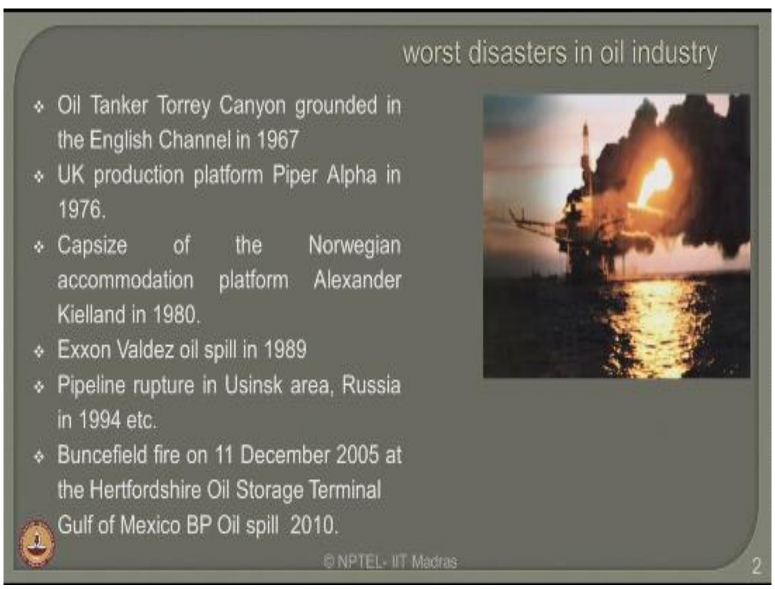

Before we look into the liquid realize modules and the details and case study in this example let us quickly see a brief summary of what are the worst disasters in oil industry. Oil tanker Torrey Canyon grounded in the English channel in 1967. UK product platform Piper alpha in 1976. Capsize of Norwegian accommodation platform Alexandra Kielland in 1980 Exxon Valdez oil spill in 1989.

Pipe line rupture in Uslink area Russia 1994. Buncefield fire on 11 December 2005 at the Hertfordshire oil storage terminal all these accidents really show a worst scenario which added to the complexity on the Gulf of Mexico BP oil spill 2010 so liquid realize models in terms of risk assessment are quantifier risk assessment place a very important role in HSE or safety.

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Therefore what is the need for the present study in terms of safety higher growth and industrialization in the last few decades resulted in numerous problems with handling and use of hydrocarbons in oil and gas industries, major accidents represents the ultimate, most disasters way in which a petroleum industry projects can go wrong. Accidents cause death suffering and pollution of the environment and disruption of business which is a very serious consideration in the economic prospective in one the vital industries of any country which is oil and gas industry.

Therefore it is important to understand the techniques to minimize these accidents through risk evaluation of various installations which are vital in the present scenario.

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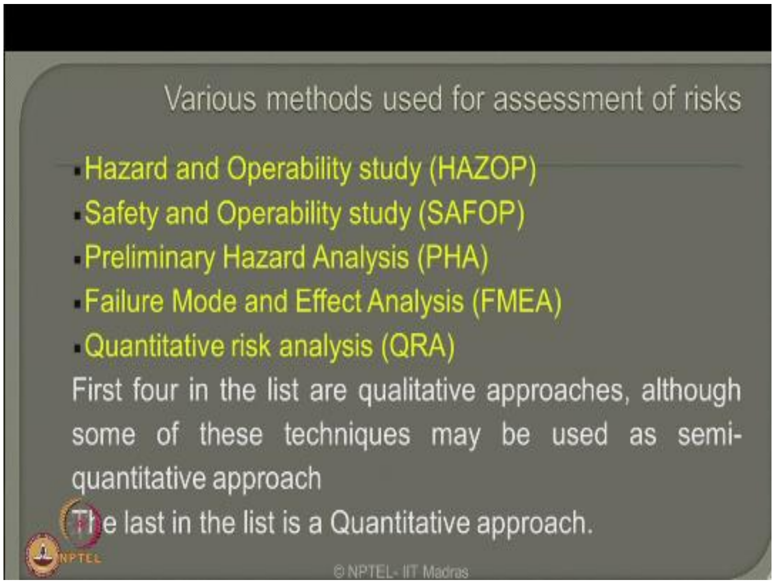

There are various methods that are used for risk assessments in oil and gas industries hazard and operability study which we call as HAZOP study which we discussed in detail in the first module with good examples safety and operability study which is SAFOP which in extension of HAZOP study which can be applied to the focus on operational safety. Preliminary hazard analysis which is PHA which is also path of hazard and deification evaluation which we did in couple of examples in the last module failure mode effect analysis which we discussed in detail with two examples case studies in newly developed design FMEA for offshore deep water production platforms.

Quantitative risk analysis which is a quantified method which is QRA in the list above ladies and gentleman the first 4 are qualitative approaches however in FMEA you have quantification of risk in terms of risk priority number where as PHA SAFOP and HAZOP are purely qualitative indications of hazard identification and analysis the last one in the list is of course they quantification of risk analysis which is now we are going to see in liquid realizes models.

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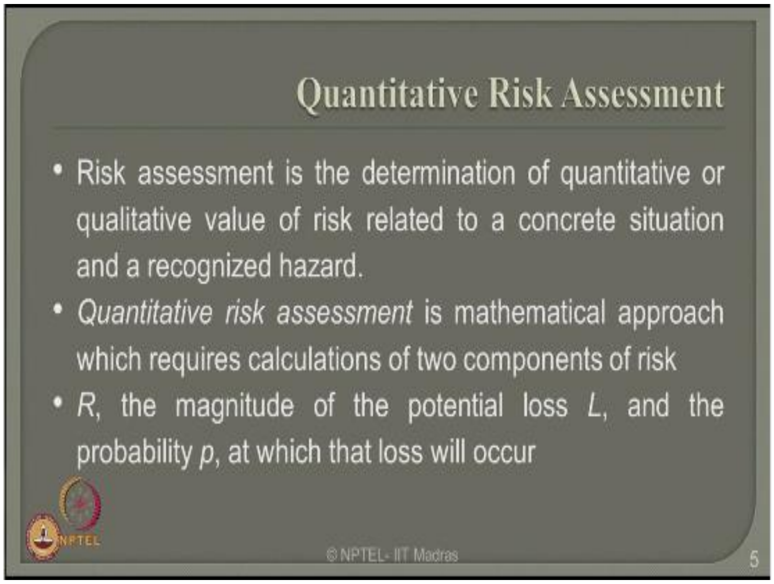

Let us talk about quantitative risk assessment methods risk assessment is essentially determination of quantitative or qualitative value of risk related to a concrete situation and a recognized hazard, quantitative risk assessment is therefore a mathematical approach which request calculations of two components of risk the first component is the magnitude of the potential loss and the second is the probability at which this loss occur so we are talking about economic prospective of risk in terms of the economic loss that can be perceived by an industry if accidents are matured enough to cause disasters as for as economic prospective is concerned.

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Fist quickly see what should be the objective or what are the objectives of QRA, estimate a risk levels and assessing their significance is the vital requirement of any ORA study it should enable us to identify the main contributors that causes risk in the industry it should be over last to define accident scenarios in term of design levels they should be able to compare different design options therefore we can either medicate risk or at least eliminate or cause risk reduction at a design stage itself evaluative risk reduction measures is a very important outcome of any QRA demonstrating acceptability to regulators.

And the workforce is a very important and vital responsibility of any oil and gas industry so that risk in terms of précised safety is also same as one of the vital goal of any oil and gas industry one should be able to identify safety crucial producers and equipments so that risk is mitigated even before a serious catastrophic accidents in encounter it is very important to identify accident precursors so that the economic loss which can result from a perceive accident can be easily minimized if it cannot be mitigated completely the flow chart.

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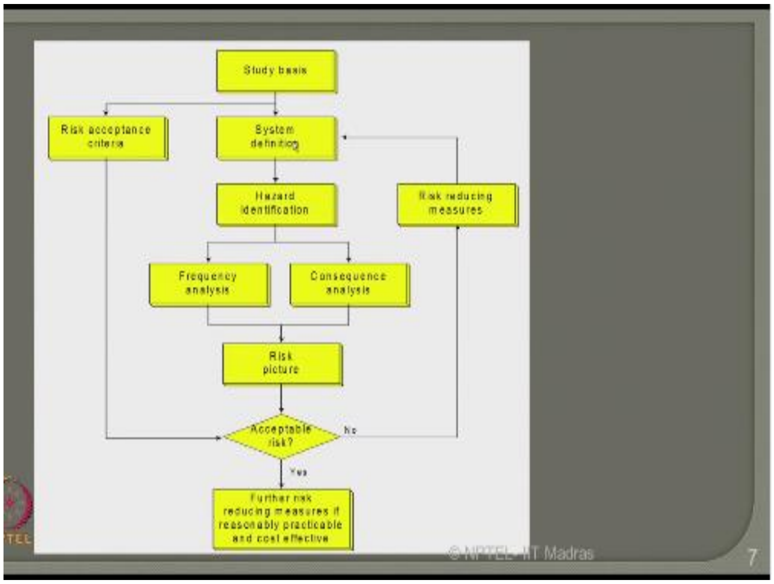

Which is seen on the screen now shows a very important guideline of QRA can be quantify let us note that study bases what is the important study requirement for a given problem for a given problem one should be able to identify the system definition then from the system define we should be able to take hold hazard identification once a system is defined prior to that for s study base is given we should be able to establish or refer to the standard available risk acceptance criteria as I told you oil and gas industry as got inbuilt risk acceptance levels which are specify by the regulatory agencies all over the world of course this be normally common for all countries but every country do follow an acceptable risk level prior to which is applicable to oil and gas industries.

So based on the predefined risk acceptance of the criteria let us define the system and try to identify the hazards which can result in scenarios of accidents then we should be a frequency analysis and the consequence analysis which we showed in the last examples which will give me compensation of what is called as risk picture then I decide whether the risk what I get here is acceptable a waste case acceptable then I preceded further.

So that I can employee risk reduction measures only with if they are practically feasible in terms of economic prospective if they are not acceptable then I must do risk reducing measures and get back to the defined definition of the system with modified design value then perform the same flow operations back again and we are going to keep on doing this until the risk picture what we get from the modified system accounts to an acceptable level of risk.

So dear friends is very important that an oil and gas industry water will be design process water may be system definition you should ultimately land up in proving to the public and to the agency that your risk perceived form the problem is within acceptable limits as long as they are not with an acceptable limits you are not suppose to execute the system and you have to keep on reversing the design or the system itself by enlarge so once the system gets an acceptable level of risk then one can talk about whether we can further mitigate risk if it is economically practical.

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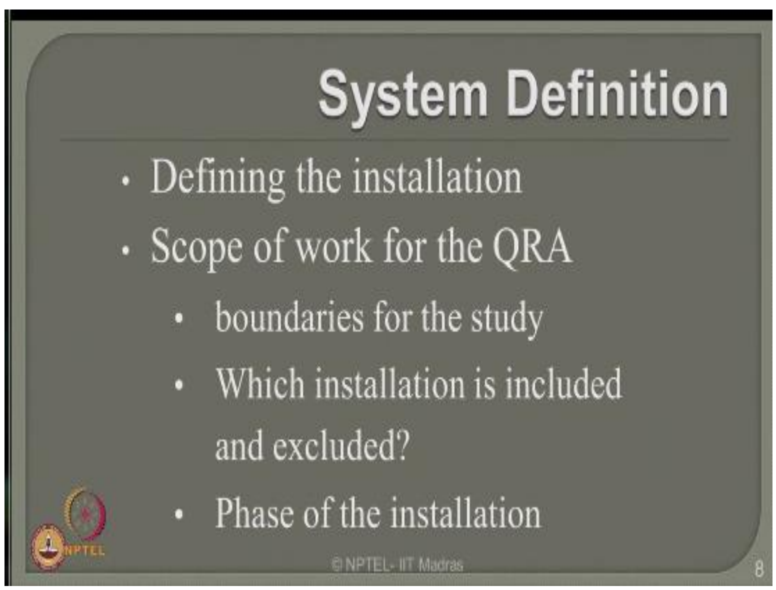

Let us talk about system definition defining installation therefore the scope of work of QRA can be one should defined the boundaries for the study as I told you any study cannot be applied to the hole plant because if you start applying any risk unless is methods for the whole plant the focus of the team of the details of perseverance of hazard or risk can be lost therefore one can divide the plant into different segments therefore it is important that one must define the boundaries for the present study they should also consider which installation should be include in eth study which can be in the study and of course you should also very clearly give a message from the report that what is the perceived or preferred face of installation of the entire project. When we talk about frequency analysis.

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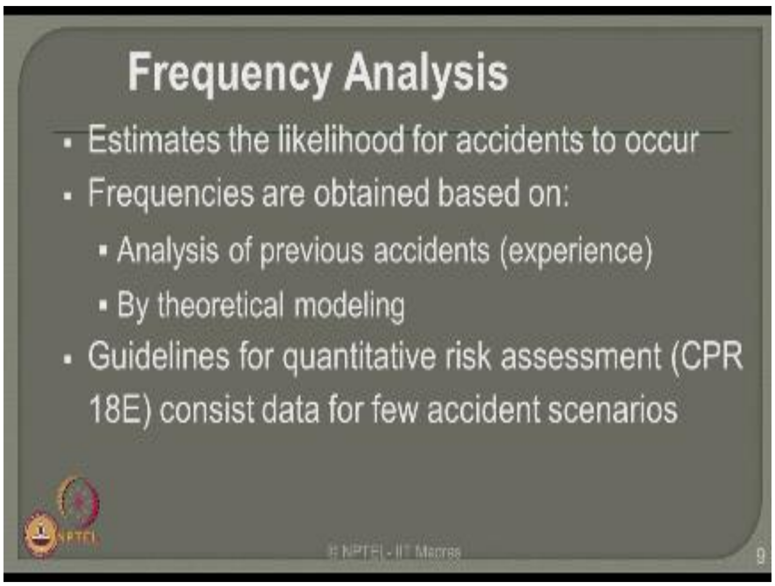

Estimates of likelihood for accidents to occur is an important part of frequency analysis, frequencies are obtained based on the following two vital characteristics, one is analyze of previous accidents based on fairly experience, secondly it can also arrive from numerical or theoretical modeling, there are different guidelines available for doing QRA one of the guideline interestingly followed in oil and gas industry is CPR 18 E which consists data for few accidents scenarios available for applicable to oil and gas industries.

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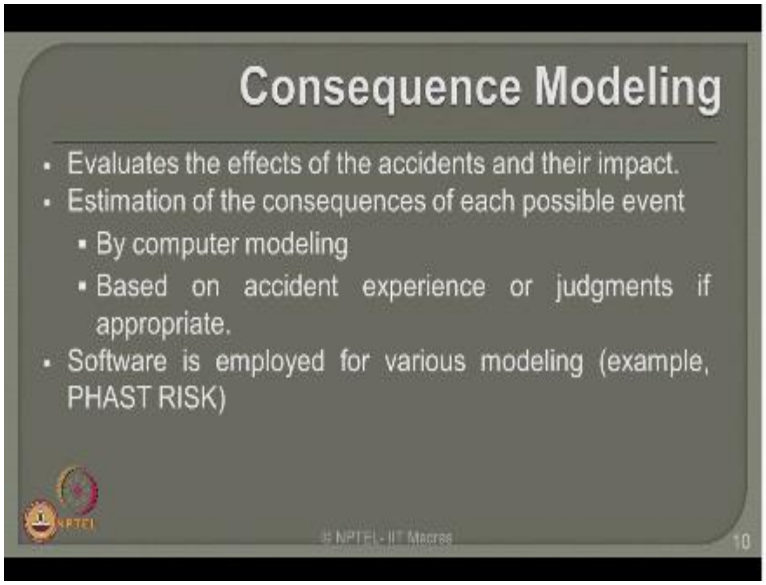

When we talk about the second component of ORA which is consequence modeling it actually evaluates the effects of the accidents and their impact on the problem, estimation of consequences of each possible events can be either done by a computer modeling or it can also be based on accident experience or judgments if they found appropriate for the applied problem, there are different software available in the market in the open domain which can be essentially used for consequence modeling one of that example is PHAST RISK given by DMB.

In the next lecture I will try to solve a problem using a specific software and which can be the hands on experience of the software very easily how a risk analysis can be used or can be easily done using one of the software, there are many software available I will explain all the software in a very brief idea in the last module of this course.

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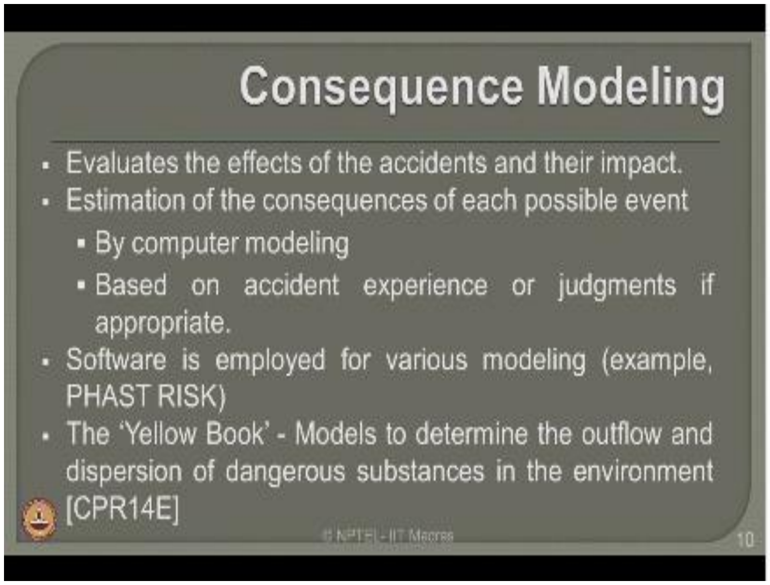

Parallely there something called a text book called yellow book which also helps you to prescribe different models that can determine the outflow and dispersion of dangerous substances in the environment which is given by the guidelines of CPR14E.

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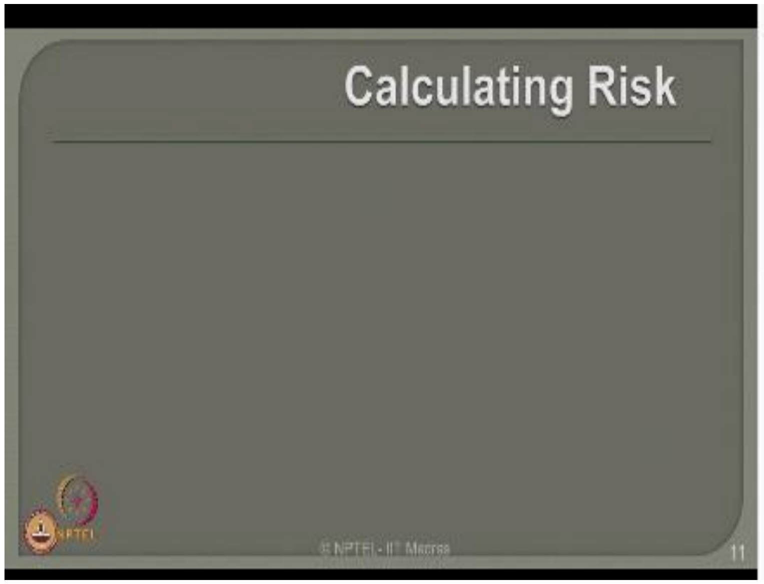

After understanding the frequency modeling and consequence modeling one is interested to know how to compute risk because we have to quantify them in terms of a number. When the frequencies and the consequences of each event in a given problem are estimated.

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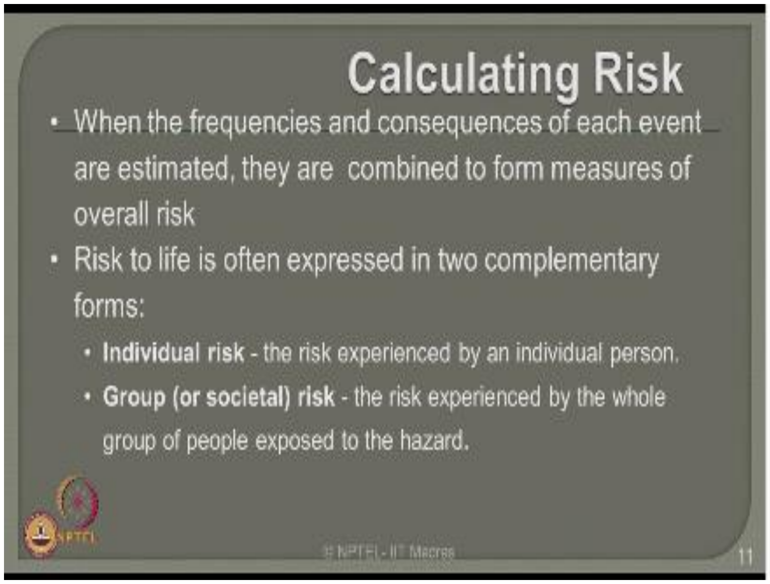

Then you can combine them to form measures of overall risk, risk to life is often expressed in two complement reforms, one is what we have already seen as individual risk which is the risk experienced by an individual person in the plant, the second can be what is called a group risk or a societal risk, this is of course very important because this is the risk experience by the whole group of people exposed to hazard that is not essentially include only people on both working in the plan.

But also population which is circumscribed located around the let sector of the plant where it is situated, so societal risk as I said in the beginning of the first module is very important for land based industry that you must not only ensure safety for your plan but also safety in terms of operation should be concern for the adjacent people living around the plant. So societal risk is also a very vital outcome of any risk analysis methods.

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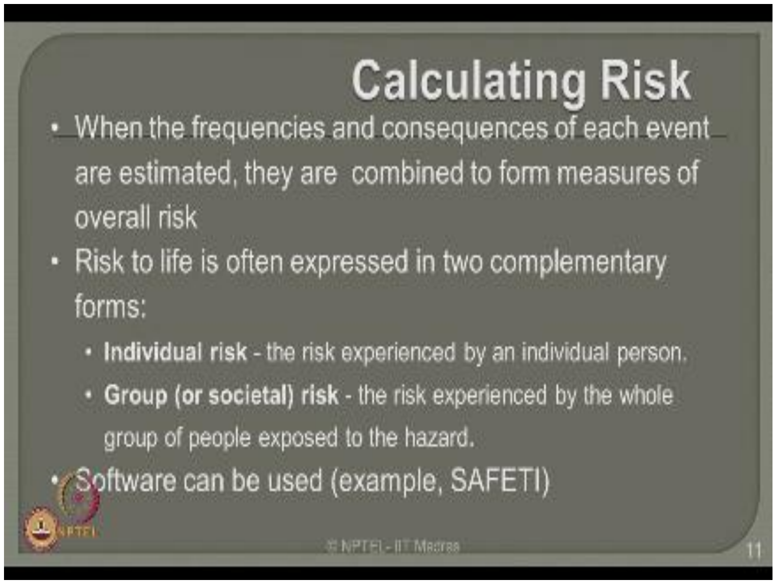

There also use other software they name SAFETI resolve is also by DLV this of course no upgraded as PHAST RISK.

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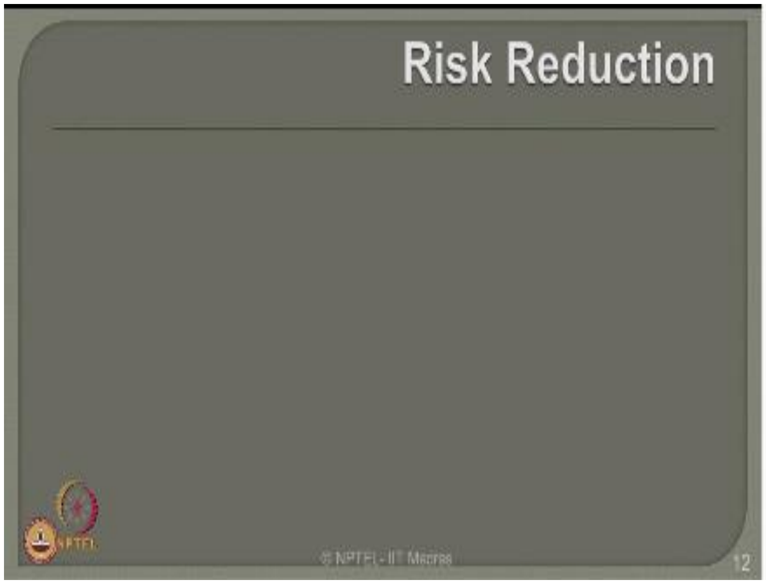

Once we understand how to compute risk or how to quantify risk in terms of consequence and frequency proportions given in a given problem then one should be able to also recommend or to identify or perceive the methods or techniques available for risk reduction.

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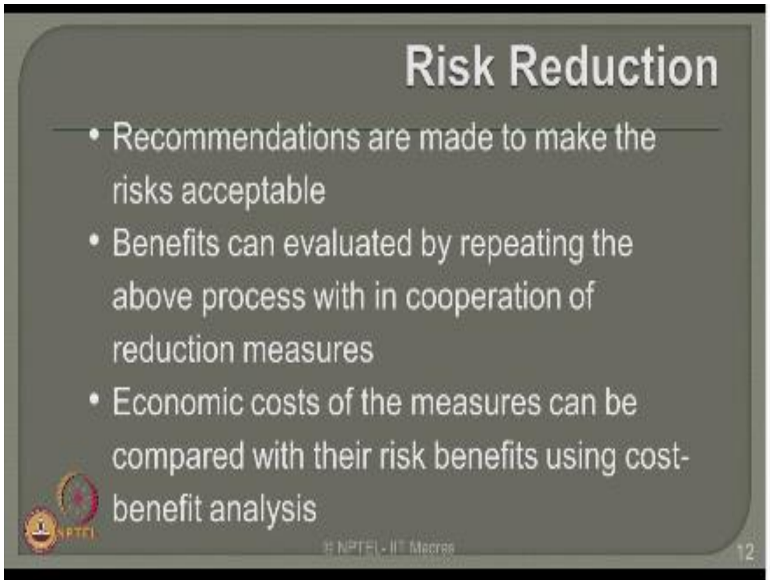

Recommendations are essentially to be made at end of the study to bring down the risk with a acceptable limits there can be benefits which should be evaluated by repeating the value process within corporation of reduction measures, one should always recommend risk reduction methods only if they are economically viable, economic consideration of the measures can be even compared with their risk benefits what you achieved by want we call cost-benefit analysis.

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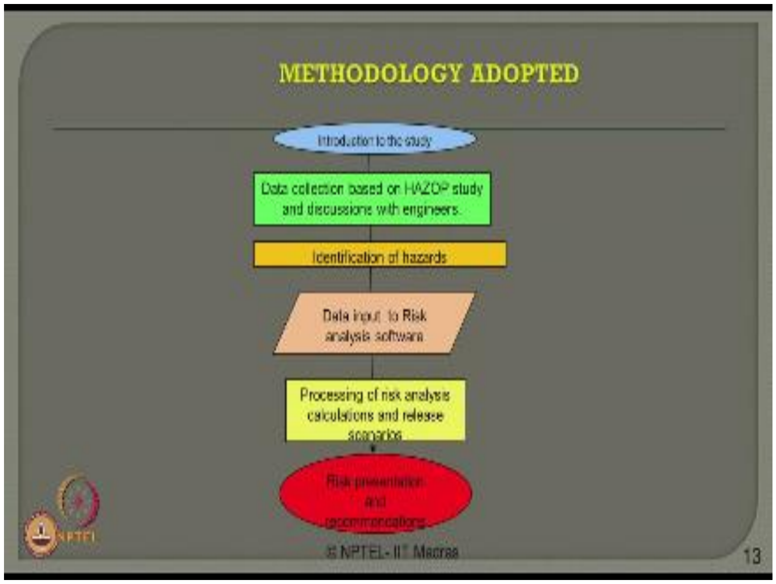

The methodology adopted for QRA is shown in a very brief cycle as you see here, let us talk about introduction to the study you must collect data based on the hazard study what you conduct and with of course discussions with engineers practicing in the industry based on the experiences gained by the surveyors conduced in Hasid dam for always identify the hazards very celery which becomes a data input to the risk analysis software, once risk analysis software is ease the data input.

Then you can do the process of risk analysis to calculate and identify different release scenarios, risk presentation and recommendations are given at the end of the flow chart so that the recommendations of risk mitigation should be always evaluated with economic perspective, risk production methods should only be recommended when the economically viable provided the risk viable should be broad within the liable or acceptable limits of current industrial standards practiced in that country.

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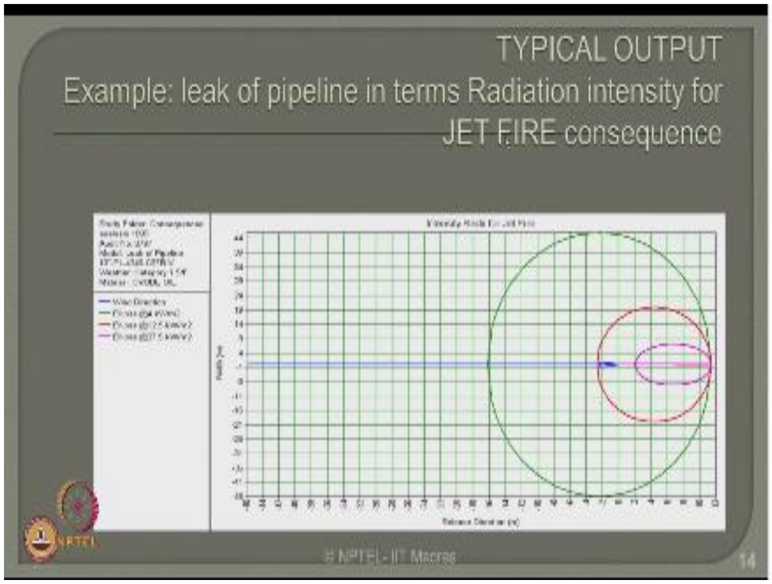

One can ask me a question if you do a software analysis for QRA what could be a typical outcome of the study, the graph shown here on the screen is a typical output of a leak over pipeline in terms of radiation intensity for a JET fire consequence, I will also show you an example of how this figures or this studies can be resulted in these kind of outcome by taking an example.

In the next lecture so this is very classical outcome of one of the consequence analysis which is been done for a specific leakage of a pipeline, the conditions used for the study are very clearly indicated here the wind direction is what you see in the blue color for example, there are different very plots which are given for different radiation intensity for example the green one shows an ellipse or radiation intensity 4 kilo watt per square meter.

So radiation intensity of 4 Kilo Watt per square meter will be available when the pipeline is ruptured for this specific circumferential radius in the intensity of the given value whereas the pink one and the orange one are respectively 37.5 kilo watt per square meter intensity and 12.3 kilo per square intensity. So we typed to mar or circumscribe the area peripheral area which allow intensity as low as 4 kilo watt per square meter and as high as 37.5 kilo watt square meter.

So this is the very interesting outcome which can be one of the outcome or the result of JET fire consequence that arise from leakage of pipeline in terms of radiation intensity.

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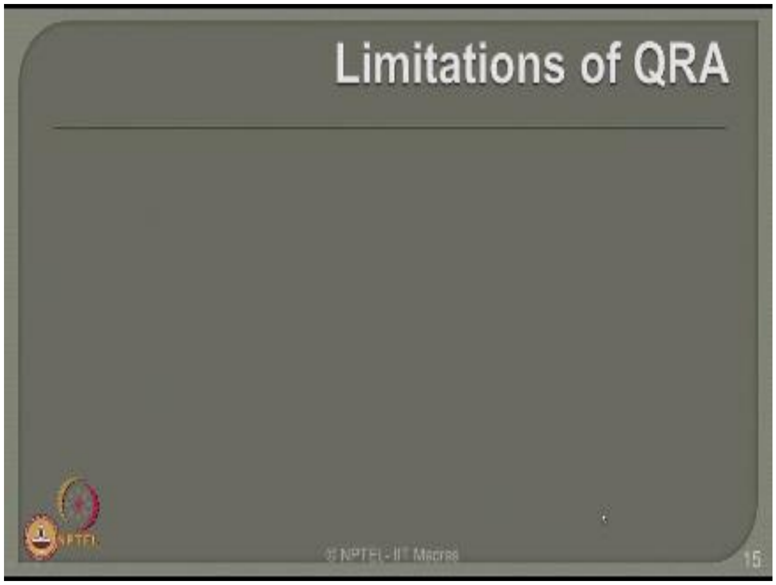

Of course, quantity of risk analysis as set a limitations let us see what are they very quickly.

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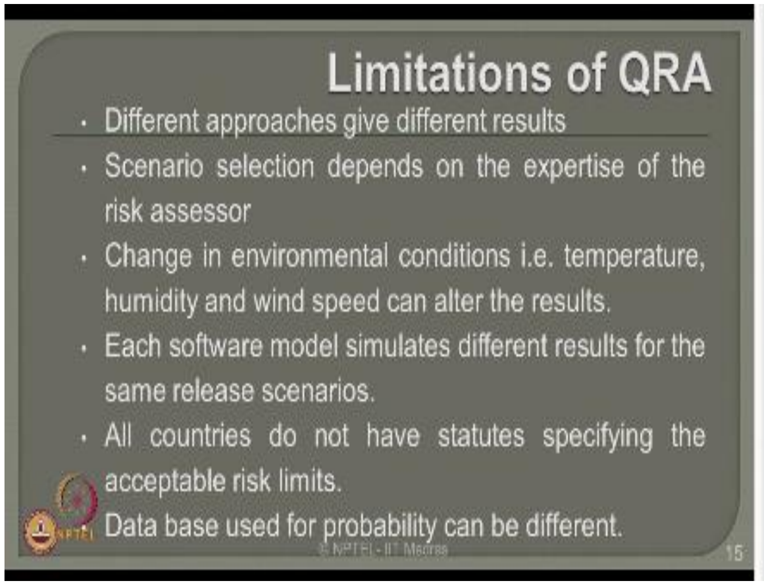

Different approached adopted for QRA unfortunately can healed different results, for scenario selection which is used for QRA very strongly depends on expertise of the risk assessor, change in environmental conditions like operational temperature, humidity and wind speed can alter the results significantly, each software model if it is not carefully done simulates different types of results for the same release scenarios.

So one should always apply justification as an outcome of the software results before it is practiced or recommended to the industry, all countries do not have statutes specifying acceptable risk limits, these very unfortunate but it is the fact, that all countries do not or may be in the stage of improving or prescribing radiated statues as of now all countries do not have acceptable statues which is applicable to oil and gas industries.

Which explicitly say it what are the acceptable risk limits in oil and gas industry, most importantly friends the data base what you are using for probability can be different for different studies and of course we all know the results of problems studies always depend on the N symbol what you give as an input to the study.

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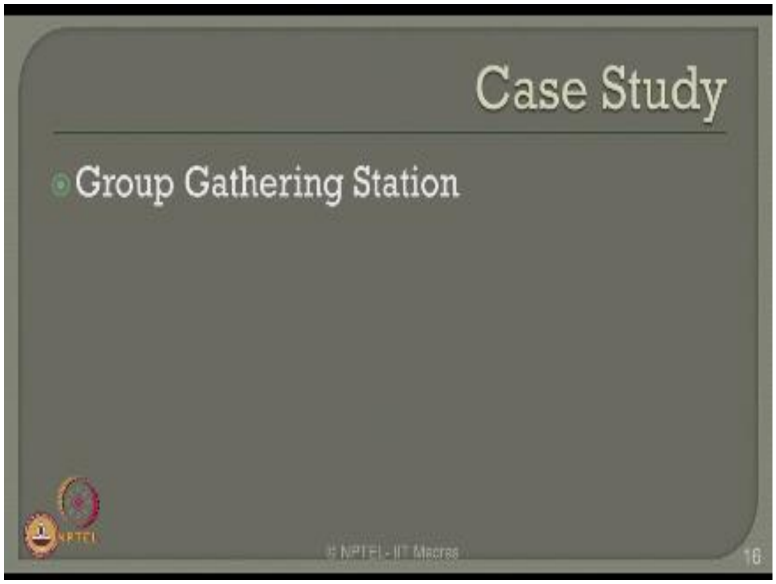

We now take of the case study apply liquid release models in this case study and show how recommendations can be derived from a case study as you see here, I am discussing the same group gathering station case study which will explore you in a HAZOP model in the previous module.

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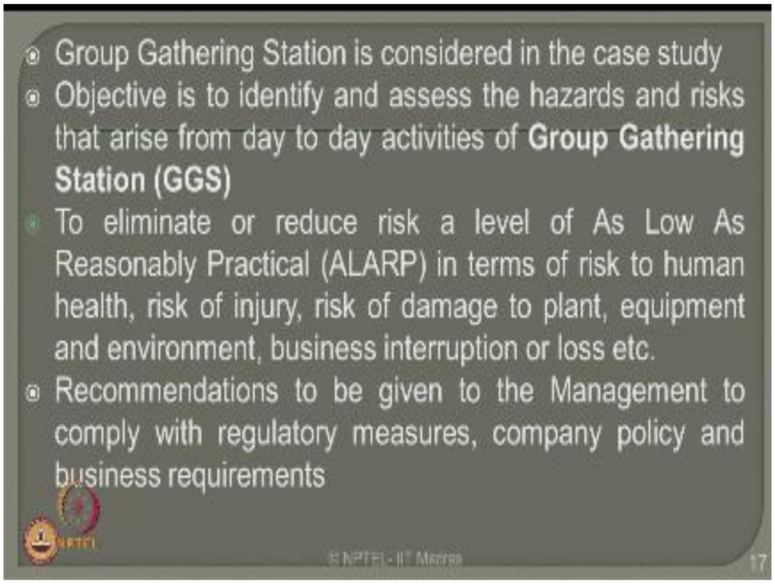

Group gathering station is presently considered for the study now the objective of the presence study in liquid at least model is to identify in access the hazards and risks that arise from day to day activities of GGS to eliminate or reduce risk a level of ALARP is being followed in terms of risk to human health risk of injury risk of damage to the plant equipments in environment business interruption or loss etc. All are consider in the current study recommendations are given at the end of the study to the management to complaint the regulatory measures company policy and business requirements.

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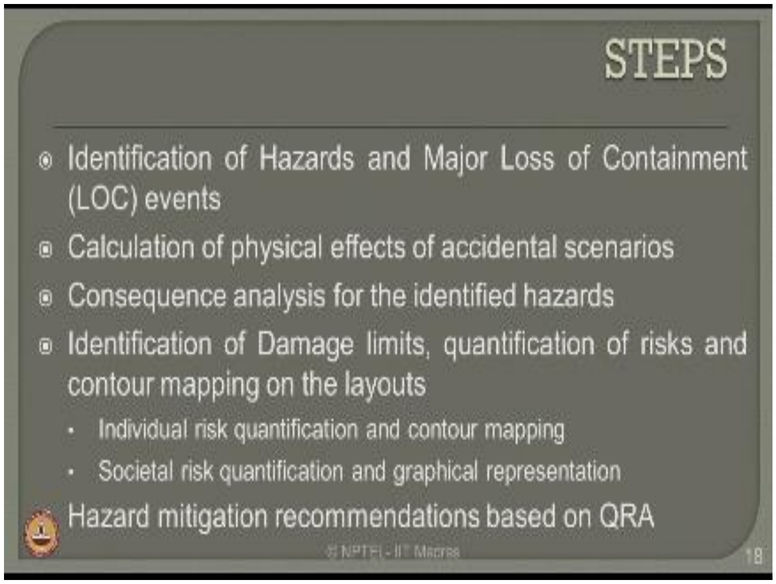

Let us quickly see what are the steps being followed in this case study the first is to identify the hazards and major loss of containment but we got LOC events followed by which it should be a calculation of physical effects of accidental scenarios then one should be a consequence analysis for the identified hazards then one should prepare identification of damage limits quantify the risks and do contour mapping of the layouts one should focus on individual risk quantification and contour mapping.

And also society risk quantification and graphical representation of societal risk that may rise from the liquid release of a GGS ultimately at the end one should also do hazard mitigation recommendations only based on the study conductor not generic recommendations.

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To conduct that we study has we all now understand there are always certain requirements that see what are the requirements which are considered in the present step piping instrumentation diagram indicating design and operating status are available to be accessor now for this present problem PFD's are given in detail to the accessor operational and control philosophies which are practiced in the GGS or understood after conducting inspection and what to service in the GGS study.

Layout drawings are specifically drawn to scale to merge them to understand what are the distances between different hazard scenarios details are fire detection and protection faculties for examine carefully which are available not only in a plan but also in the vicinity details of emergency shutdown system if applicable in the plant are carefully taken or consider in the recommendations of course most importantly.

Details of population located around the plan is also construct the study because based on which societal risk can be evaluated.

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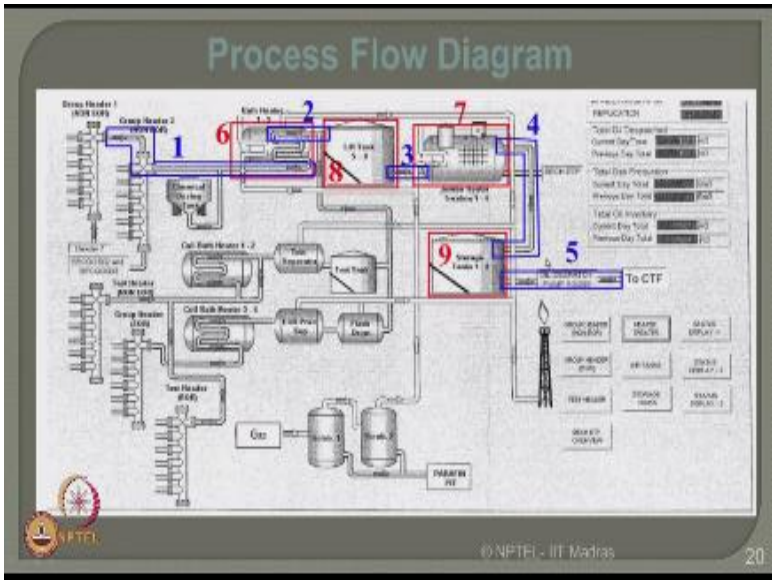

The process for diagram what we see here is as same as what we have seen in the previous case in the hazop study but interestingly if you see here there are different segments marked in colors of one two three four five six seven eight nine some of the points are given in blue and some of the points are shown in red there are very interesting features the points which are shown are the statements which are shown in here do you indicate risk of very high order based on the studies so the results obtained from the study.

Of super imposed on the process flow diagram for a easy understanding of the process engineer to know which are the statements which are high risk which are the segments in a plan is just not have higher risk or which high risk within a lot levels.

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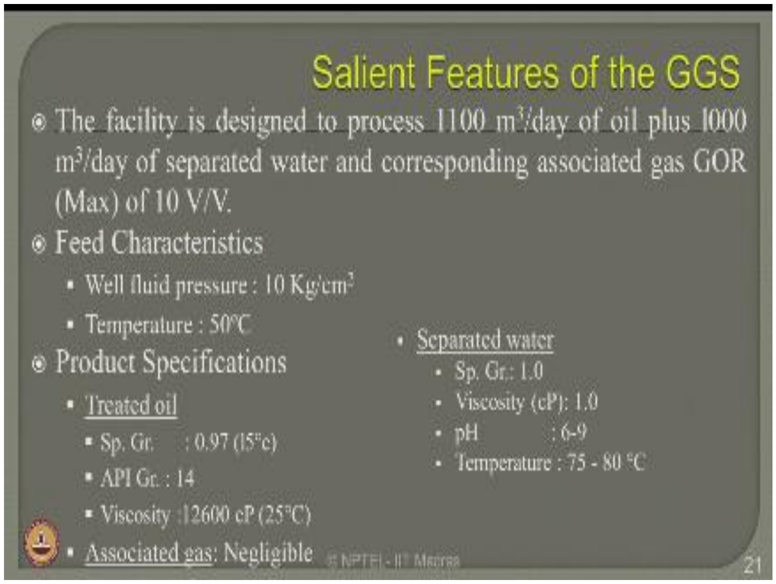

Let us quickly recollect the salient features of group gathering station which you already know that is still the facility is designed to process 1100m^3/day of oil plus 1000m^3/day of separated water and the corresponding associated GOR is about 10V/V. The feed characteristics which are given to the station are the following. The well fluid pressure is about 10Kg/cm^2 the outpatient temperature is 50 degree C the product specification are the following the treated oil in the group gathering discussion has specific gravity of over 0.97 at 15 degree C and it is of API grade 14.

The viscosity of the oil treated in group gathering discussion is about 12600cP at 25 degree C. The associated gas in the station is highly negligible if you look at the separated water from the process station of GGS the specific rate of water is the one with the cP viscosity of 1.0 the ph of the water separated range is from 6 to 9 the temperature operation is about 75 to 80 degree C.

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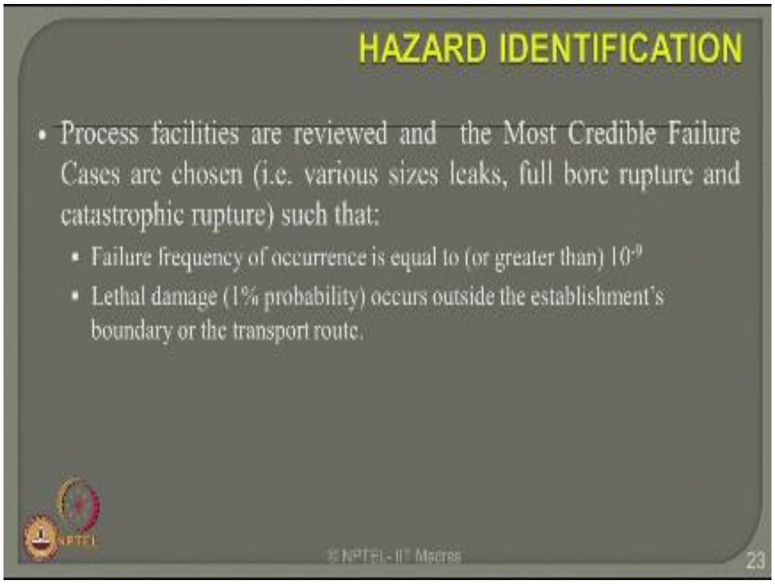

Let us now see what are different hazards identify in the group guide and session in different segments marked as 1 to 9 in the process flow diagram the process facilities are carefully reviewed and the most credible failure cases from the process industry as in case of this case as group gathering station is carefully chosen now when we ask the question what are those most credible failure scenarios which are chosen for the present study various sizes if week ages full bore rupture.

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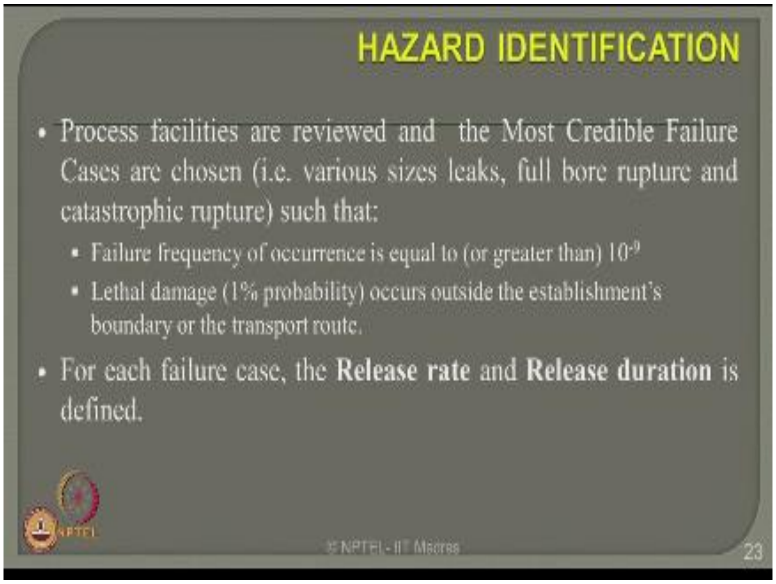

And catastrophic rupture or some of the examples which are consider as MCF that is most credible failure cases in the present study the failure frequency of occurrence is either equal to or greater than 10^{-9} the quantity done or the qualify done as credible failure the lethal damage which in cause the such failures should have at least one present probability that occurs outside the establishments boundary or the transport route so to qualify the specific failure as a most credible failure in a given section of the plan apart from.

Identifying the various sources of makes bore rupture and catastrophic rupture one should also see what are the failures frequencies of the occurrences and what would be the lethal damage cost to society around the plan based on these two values can always identifying unless most credible failures scenarios like given plant once you know them then for each failure case you must estimate the release rate and release duration is very important because already we studies in the last lecture in module 2.

What we talk about the lethal damage and lethal dosage is etc. So it all depends upon at what rate the chemical or the gas is released and where is the duration release because it will tell you whether.

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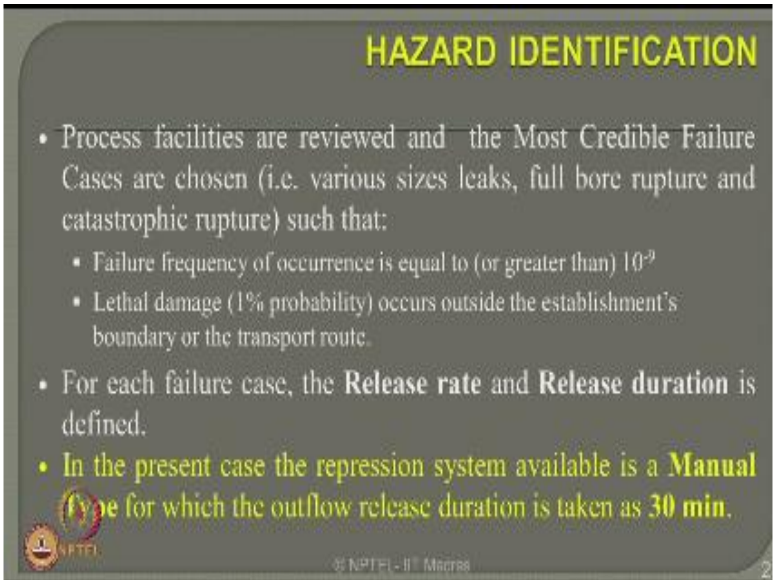

The contamination or concentration of liquid release is what we called as liquid quantity in chemical exposure index what is a duration of that release is very important so please pre define the release rate and release duration for each failure case as identify as most credible failure case in augment system once you do this in the present case for example the repression system is available which is very important to note it is a manual type for which the outflow release duration is taken as 30 minutes.

So flow very automatic suppression system available in the plant then we can always consider the release duration are the contain mechanism of that duration in your study because this place is a very important role in giving final recommendations for the risk mitigation and control.

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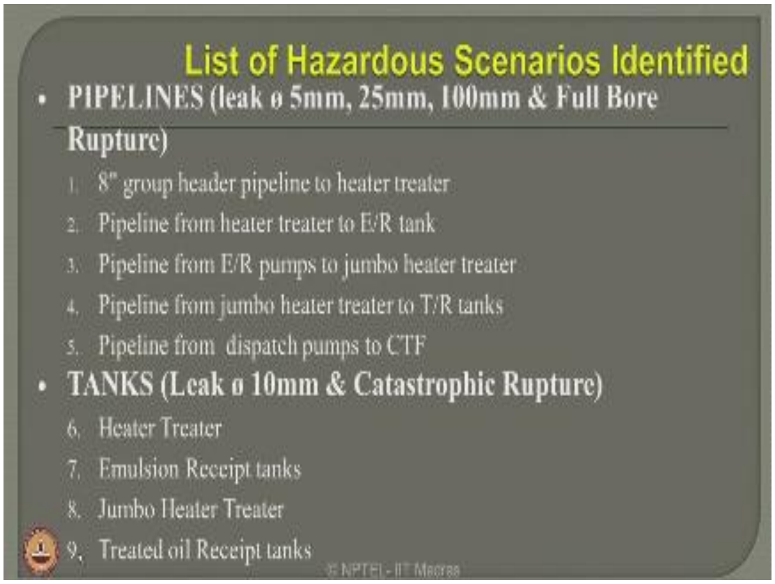

Whereas quickly see what are the list of hazards scenarios identify in the given plant there are two cases identified separately one is for the pipeline one is for the tanks for the pipeline the leak diameter is 5mm 25mm, 100mm and full bore lecture 8" group whether pipeline is heater treater is one segment which is got this kind of hazard scenario pipeline which travels from heater treater to emulsion receipt tank is another area pipeline from ER pumps to Jumbo heater treater is another segment where.

Leak scenario is identified pipelines from jumbo heater treater to TR tanks is also another area where leaks can be identify pipeline from dispatch pumps to CTF that is common tank facility is another area where the leak scenario is identified in the present study now these are as for the pipelines are concerned the leak scenario is also identify at the tank levels at 10mm diameter rupture and catastrophic rupture which can happen at heater treater emulsion in the receipt tanks jumbo heater treater.

And treated oil receipt tanks what is called TR tanks so the rupture can happen either in the tanks or in the pipelines verify the scenarios identified as the number how 1 to 9 as you saw in the process flow diagram in the beginning of this presentation.

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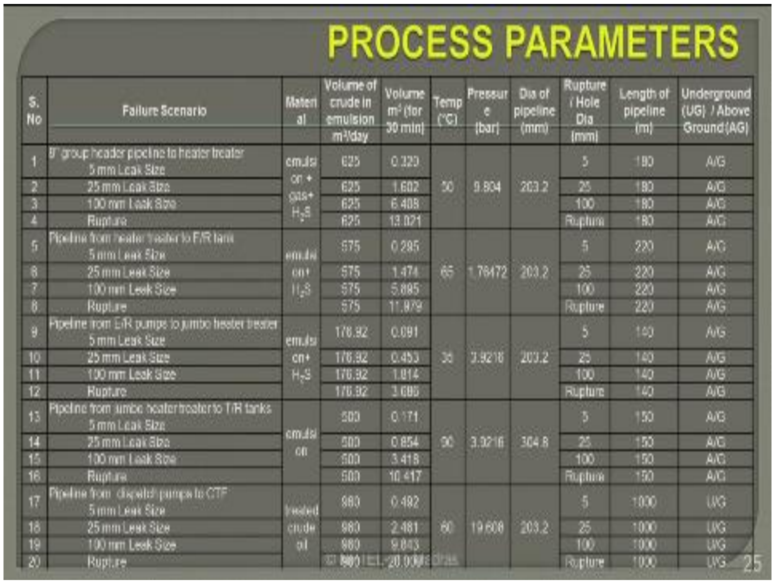

PROCESS PARAMETERS

S. No	Failure Scenario	Material	Volume of crude in emulsion m^3/day	Volume m^3 (for 30 min)	Temp (°C)	Pressure (bar)	Dia of pipeline (mm)	Rupture / Hole Dia (mm)	Length of pipeline (m)	Underground (UG) / Above Ground (AG)
1	8" group header pipeline to heater treater 5 mm Leak Size	emulsion + gas+ H_2S	625	0.320				5	180	A/G
2	25 mm Leak Size		625	1.602	50	9.804	203.2	25	180	A/G
3	100 mm Leak Size		625	6.408				100	180	A/G
4	Rupture		625	13.021				Rupture	180	A/G
5	Pipeline from heater treater to E/R tank 5 mm Leak Size	emulsion+ H_2S	575	0.295				5	220	A/G
6	25 mm Leak Size		575	1.474	65	1.78472	203.2	25	220	A/G
7	100 mm Leak Size		575	5.895				100	220	A/G
8	Rupture		575	11.979				Rupture	220	A/G
9	Pipeline from E/R pumps to jumbo heater treater 5 mm Leak Size	emulsion+ H_2S	176.92	0.091				5	140	A/G
10	25 mm Leak Size		176.92	0.453	35	3.9216	203.2	25	140	A/G
11	100 mm Leak Size		176.92	1.814				100	140	A/G
12	Rupture		176.92	3.686				Rupture	140	A/G
13	Pipeline from jumbo heater treater to T/R tanks 5 mm Leak Size	emulsion	500	0.171				5	150	A/G
14	25 mm Leak Size		500	0.854	90	3.9216	304.8	25	150	A/G
15	100 mm Leak Size		500	3.418				100	150	A/G
16	Rupture		500	10.417				Rupture	150	A/G
17	Pipeline from dispatch pumps to CTF 5 mm Leak Size	treated crude oil	980	0.492				5	1000	U/G
18	25 mm Leak Size		980	2.481	60	19.608	203.2	25	1000	U/G
19	100 mm Leak Size		980	9.843				100	1000	U/G
20	Rupture		980	[illegible]				Rupture	1000	U/G

Let us quickly see what are the process parameters considered in the study, if we talk about the scenarios of 8 inch group where pipeline to heater treated and we talk about 5mm leak your size, 25mm leak size, 100 mm leak size and rupture. The material is emulsion plus gas plus hydrogen and sulphur. The volume is specific as 625 cubic meter per day which is taken as a statistical value available in the plant. The volume for 30 minute exposure is also considered because this for day and you always calculate this for 30 minutes interval.

You already know what are the operation temperature of this particular group header pipeline in heater treated. We also know where is a pressure and diameter the pipeline at which it is being operated, whereas dia about different scenarios of 5 mm leak, 25 mm leak, 100 mm leak and whole board rupture. The length of the pipeline in meters available here which is physically measure in the plant and we have sorts of classify whether the pipeline is above ground or underground.

So as such kinds of studies of failure scenario are done for group header pipeline, pipeline that travels when heater treater to E/R tank pipeline from E/R pumps to jumbo heater treater, pipelines from jumbo heater to treater to T/R tanks and pipeline from dispatch pumps to common tank facility. So all individual scenarios will each one of the guidelines are quantified and process parameters varying from the volume per exposure of 30 minutes, temperature, pressure and the rupture consequences and length of the different pipelines are quantified in a given problem before QRA is attempted for the segment of pipeline failure.

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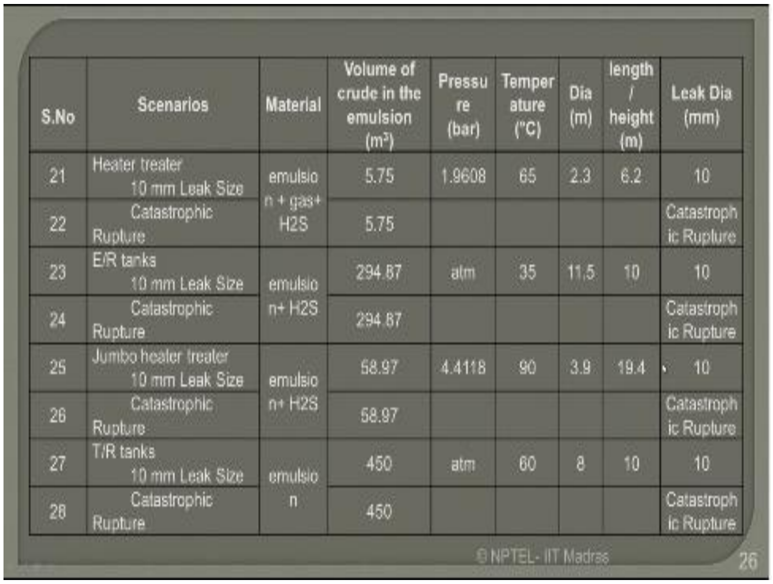

S.No	Scenarios	Material	Volume of crude in the emulsion (m^3)	Pressure (bar)	Temperature (°C)	Dia (m)	length / height (m)	Leak Dia (mm)
21	Heater treater 10 mm Leak Size	emulsion + gas+ H2S	5.75	1.9608	65	2.3	6.2	10
22	Catastrophic Rupture		5.75					Catastrophic Rupture
23	E/R tanks 10 mm Leak Size	emulsion+ H2S	294.87	atm	35	11.5	10	10
24	Catastrophic Rupture		294.87					Catastrophic Rupture
25	Jumbo heater treater 10 mm Leak Size	emulsion+ H2S	58.97	4.4118	90	3.9	19.4	10
26	Catastrophic Rupture		58.97					Catastrophic Rupture
27	T/R tanks 10 mm Leak Size	emulsion	450	atm	60	8	10	10
28	Catastrophic Rupture		450					Catastrophic Rupture

Similarly for the tanks also they identify the heater treater, the E/R tanks, the jumbo heater treater and T/R tanks. We were the possible four tanks where 10 mm leak size and catastrophic rupture can take place they are quantified the materials classify volume is no, pressure, temperature, diameter in length or height of the tank they are this what the liquid release rate can be completed is quantified and then the leak diameter in terms of either 10 mm leak size catastrophic rupture is quantified for QRA.

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Once the process conditions are parameters are evaluated for the given segment of the PFD then we also consider the weather conditions for analysis.

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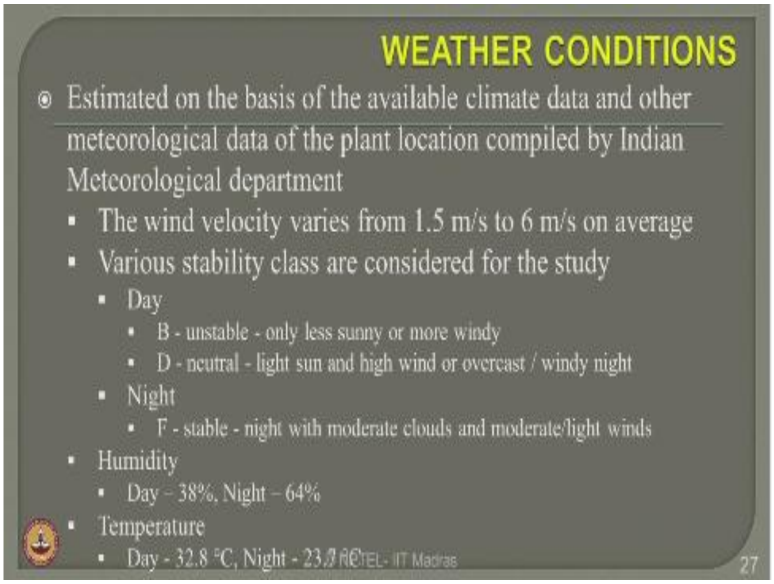

In the present study the weather condition is estimated on the basis of available climate data and other meteorological data of the plant location complied by IMD. The wind velocity is varying from 1.5 m/s to 6 m/s on an average. Various stability class are then considered for the study for example, in the day class is considered to be B and D. B refers to unstable class only less sunny and more windy. D refers to a neutral class which is got light sun and high wind or overcast windy night.

Whereas for the night stability class we have assume F, which is the stable class night with moderate clouds and light winds. The humidity in the day time is 38% the night time 64%, temperature in the day time was 32.8˚C and night it is 23.7˚C which are considered as input for the analysis as for as a weather parameters are considered.

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When we perform the consequence analysis.

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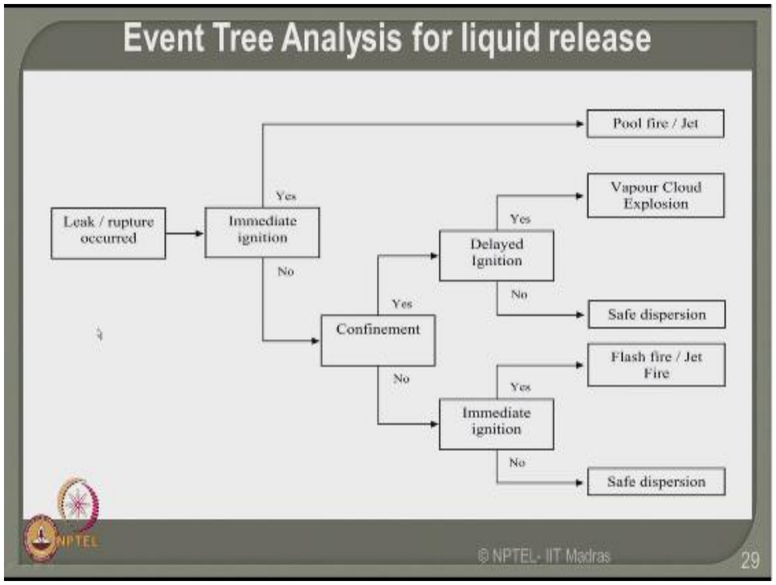

We calculated the event trees for the liquid release, the liquid can be either a leak or a rupture occurrence it can be cause immediate ignition it will results immediate ignition it can result in pool fire if it does not cost immediate ignition it can is confined a specific area, if the confinement is effective then there is a delayed ignition which you can result in VCE what we call vapour cloud explosion. If the delayed ignition is not there if it is rich instantaneous when we talk about safe dispersion.

In the convenience is not successful within the dice then it can again cause immediate ignition which can result in flash fire or a safe dispersion. So we perform event tree analysis to know the consequences of various scenarios.

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Whereas no quickly you get the results which have been done using a software for a specific problem.

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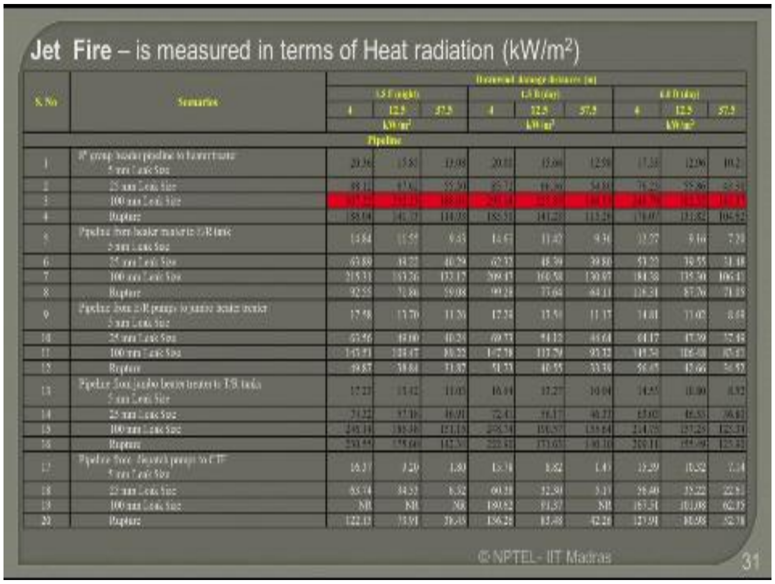

Let us first take the jet fire as one of the outcome of the study. Jet fire in this problem is measured in terms of heat radiation which is kW/m^2. Now there are different scenarios identifying the problem as 8 inches group header, pipeline from heater treater, pipeline from E/R tanks, pipeline from jumbo heater treater and pipeline dispatch comes the quantification available for downward damage distances in meters are given in the table of form here.

The red volume you have to see here is the value which results in unacceptable risk levels. For example, 8 inches group header pipeline which is going to heater treater which results in 100 mm leak size has caused an unacceptable damage downward distance which is not in the standards acceptable to a specific industry according to specific guidelines available for that industry.

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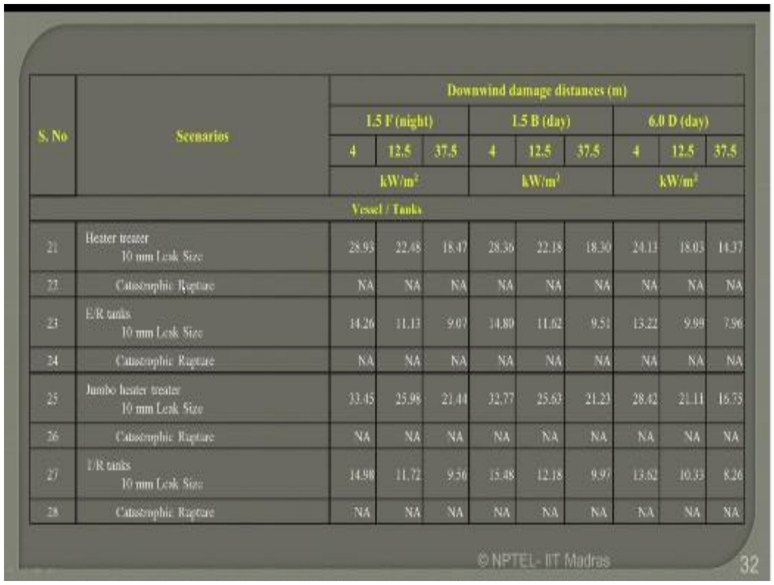

S. No	Scenarios	Downwind damage distances (m)								
		1.5 F (night)			1.5 B (day)			6.0 D (day)		
		4	12.5	37.5	4	12.5	37.5	4	12.5	37.5
		kW/m²			kW/m²			kW/m²		
Vessel / Tanks										
21	Heater treater 10 mm Leak Size	28.93	22.48	18.47	28.36	22.18	18.30	24.13	18.03	14.37
22	Catastrophic Rupture	NA	NA	NA	NA	NA	NA	NA	NA	NA
23	E/R tanks 10 mm Leak Size	14.26	11.13	9.07	14.80	11.62	9.51	13.22	9.99	7.96
24	Catastrophic Rupture	NA	NA	NA	NA	NA	NA	NA	NA	NA
25	Jumbo heater treater 10 mm Leak Size	33.45	25.98	21.44	32.77	25.63	21.23	28.42	21.11	16.75
26	Catastrophic Rupture	NA	NA	NA	NA	NA	NA	NA	NA	NA
27	T/R tanks 10 mm Leak Size	14.98	11.72	9.56	15.48	12.18	9.97	13.62	10.33	8.26
28	Catastrophic Rupture	NA	NA	NA	NA	NA	NA	NA	NA	NA

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Similarly we will talk about the tankers the different scenarios again in terms of downward damage distances are evaluated in terms of its class for stability as F for night B and D for day time, in terms of radiation of 4, 12.5 and 37.5 radiation intensity in terms of kW/m^2. Dear friends these are the three categories of radiation intensity for a jet pool fire as recommended to be considered for safety studies as for as industry standards are concerned in India.

So for the different vessels and tanks which are been identify as leak scenarios heater treater, emulsion to E/R tanks, jumbo heater treaters T/R tanks for different scenarios the damage downward distances in heaters are available for different scenarios then this leak or this ruptures are in this aged.

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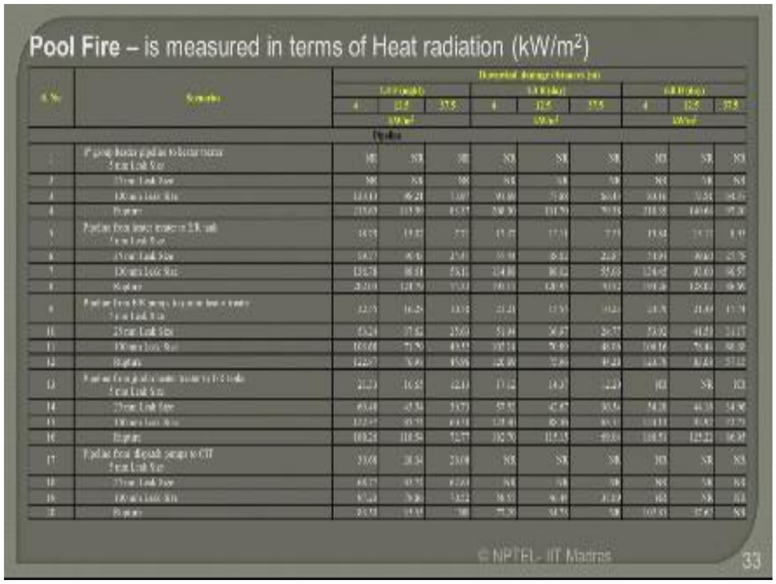

The second scenario study is pool fire is also measure in term of heat radiation in kW/m^2 similarly for different scenarios for the pipeline and different scenarios for the tankers or vessels the downward damage distances in meters are evaluated and determine from the software for a given scenario of 5 mm leak size, 20 mm leak size, 100 mm leak size and whole pool rupture for different locations of heater treater E/R tank, jumbo heater treater T/R tanks and pipelines which goes from the pump to the CTF.

These are the scenarios identify as hazard scenarios in the given problem and the downward damage distances for different pass of stability for day and night, for different heat radiation intensities as specified by the regulatory agency are worked out in terms of distances in meters. You will see here that all these distances are acceptable standards which is within risk accepters levels for the given regulatory agency.

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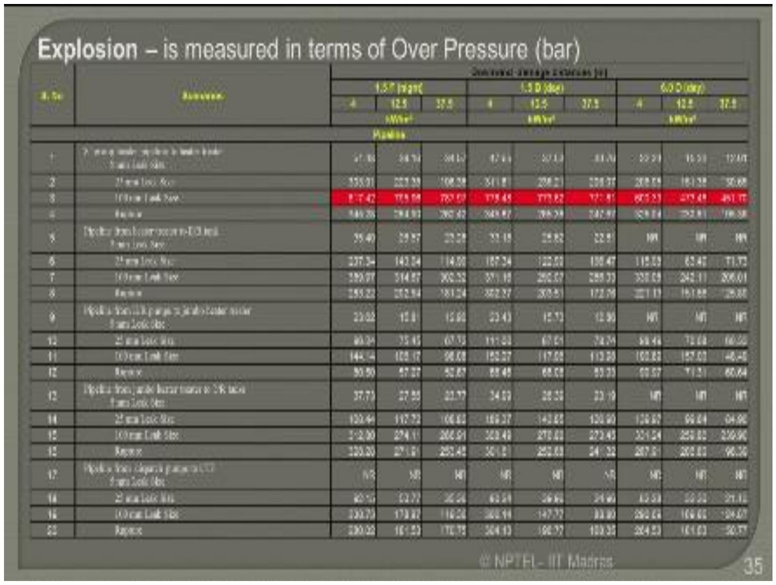

When we talk about the tankers failure for pool fire especially in terms of catastrophic rupture that could happen in emulsion the CPN tank the distances which are shown in red here are the red mate are unacceptable in terms of risk acceptance criteria for the given plant. The third parameter considered for the analysis here is explosion which is measured in terms of over pressure as bar for different stability class and night and day for different scenarios from the pipeline we are identify the over pressure occurred because of the different scenarios of failure, if we look that they eight inters group header pipeline to heat theta when you result ort when you envisage under on leak sides for eight inches group header it can cause in over pressure which is unacceptable by industrial standard practice by this agency.

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S. No	Scenarios	Downwind damage distances (m)								
		1.5 F (night)			1.5 B (day)			6.0 D (day)		
		4	12.5	37.5	4	12.5	37.5	4	12.5	37.5
		kW/m²			kW/m²			kW/m²		
	Vessel / Tanks									
21	Heater treater 10 mm Leak Size	100.84	75.01	62.48	75.88	56.78	47.84	40.94	28.90	24.46
22	Catastrophic Rupture	304.26	192.86	151.37	270.70	171.17	130.28	241.19	148.30	122.46
23	E/R tanks 10 mm Leak Size	36.87	26.77	23.38	68.06	41.97	36.98	18.57	13.70	11.86
24	Catastrophic Rupture	368.77	245.38	202.84	353.51	233.66	196.50	300.37	200.58	105.01
25	Jumbo heater treater 10 mm Leak Size	80.62	66.00	58.44	87.49	66.00	57.08	56.07	40.69	35.34
26	Catastrophic Rupture	606.58	396.71	322.66	602.01	394.88	326.22	538.44	359.00	294.76
27	T/R tanks 10 mm Leak Size	31.52	24.81	22.46	34.58	26.18	23.09	NR	NR	NR
28	Catastrophic Rupture	516.80	351.48	206.87	449.28	301.06	256.04	383.12	251.54	229.87

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Similarly when you talk about the scenario apply to vessels or tankers or these over pressure values in terms of bar are acceptable standards as for as OSID is concerned for this specific plant.

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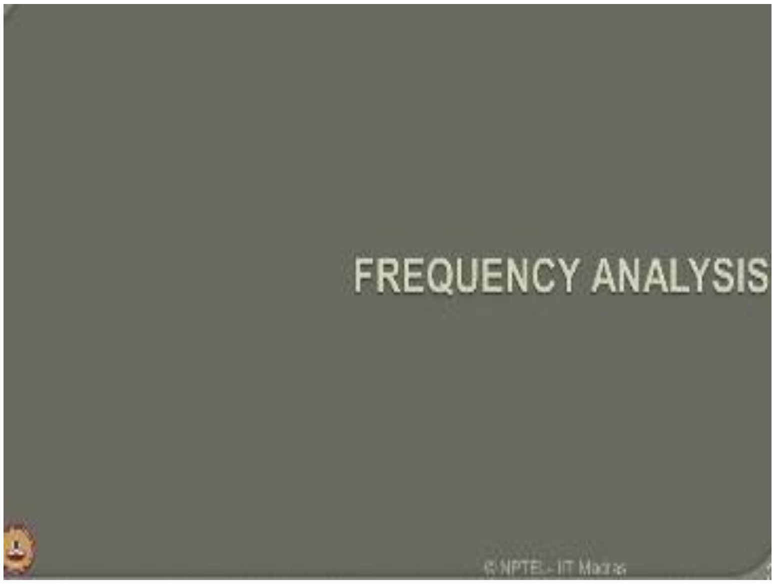

Then we perform the frequency analysis base on the risk estimates but we got in term of the results in the previous slide.

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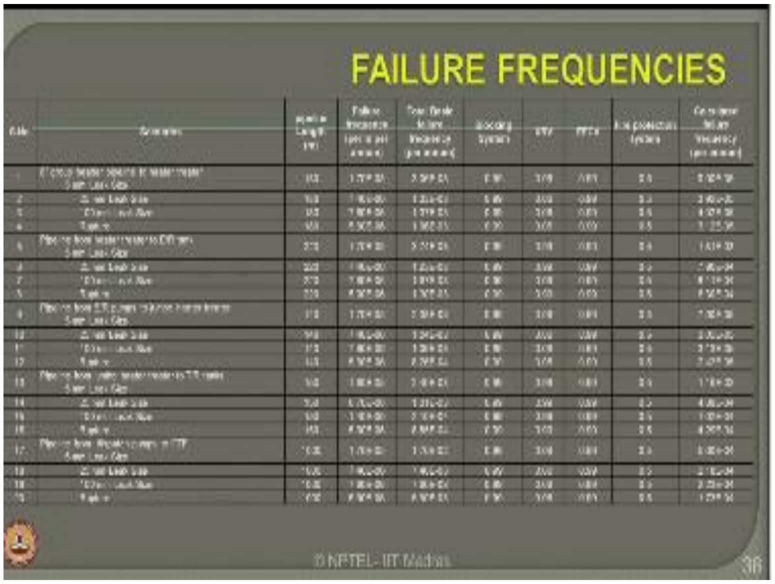

Then we estimated the failure frequencies for Annam which is computed from the software for the given input data for the scenarios is identified as eight inches group had a pipeline, pipeline Lear tanks heater theta etc the pipeline links already I has been identify the begging of the presentation the failure frequency permit a Para numbers known based on which the blocking system is also input in the given analysis.

Then the fire protection system available in this scenario is considered and then the frequency of failure analysis in terms of failure frequency Para num is computed this value are compare with acceptable failure frequency for the given standard regulatory measures for this industry and all unacceptable value are banned in red in colour in the results.

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S.No	Scenarios	Total Basic failure frequency (per annum)	Blocking System	NRV	EFCV	Fire protection system	Calculated failure frequency (per annum)
21	Heater treater 10 mm Leak Size	2.80E-03	0.99	0.98	0.99	0.5	1.36E-03
22	Catastrophic Rupture	3.00E-06	0.99	0.98	0.99	0.5	1.46E-06
23	FR tanks 10 mm Leak Size	2.80E-03	0.99	0.98	0.99	0.5	1.36E-03
24	Catastrophic Rupture	3.00E-06	0.99	0.98	0.99	0.5	1.46E-06
25	Jumbo heater treater 10 mm Leak Size	2.80E-03	0.99	0.06	0.99	0.5	8.23E-05
26	Catastrophic Rupture	3.00E-06	0.99	0.06	0.99	0.5	8.82E-08
27	T/R tanks 10 mm Leak Size	2.80E-03	0.99	0.98	0.99	0.5	1.36E-03
28	Catastrophic Rupture	3.00E-06	0.99	0.98	0.99	0.5	1.46E-06

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The same study of frequency analysis in terms of estimating failure frequency Para num is also computed for the vessels and tankers of heater theta emergency CPN tanks jumbo heater theta and TR tanks for the different rupture and leak size resume in the analysis.

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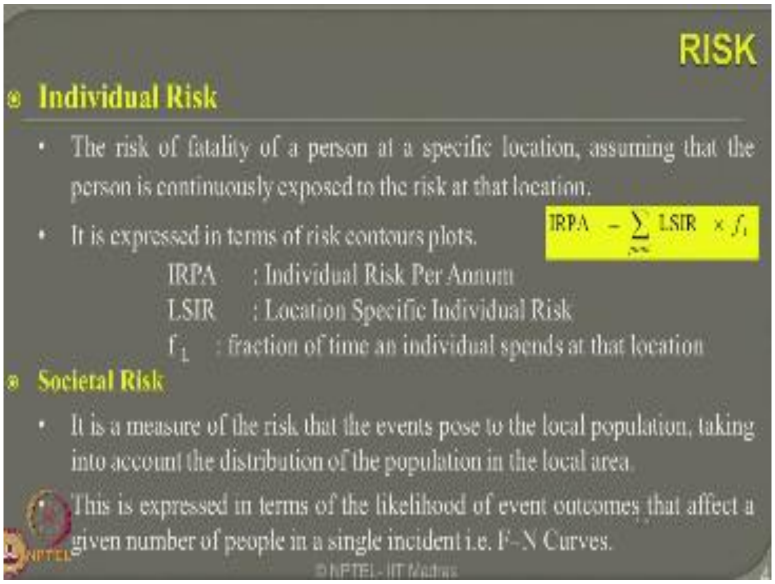

Now base on this two frequency and consequences risk is estimated for the given study there are two cases as which we estimate one is the individual risk other is societal risk, individual risk the risk of fatality of a person at the specific location assuming that the person is continuous expose risk at that location. This is can be easily computed as individual risk for Per Annum which is given as IRPA which is given by the equation shown on the right side.

That LSIR is the location specific individual risk in a specific location of the plant and Fl is a fraction of time and individuals spend of that location so if you know this do the term some them up and try to get the individual Per Annum estimated for the given scenario and the given plant talk about societal risk it is of course a measure of risk that the event sources to the local population taking of the account the distribution of population in the local area.

This expose in terms of like viewer or view once outcome that affect a given number of people in a single incident which is measured in terms of FN curves.

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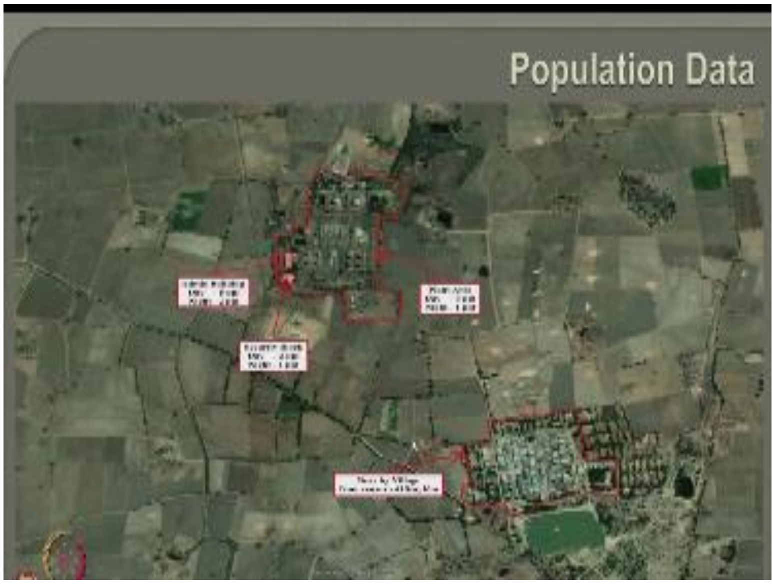

Now it is interesting to know what is the population data be considered for the given scenario that population data in terms of admin building security block near the village and plant area or taken from the reason senses the normal village has a population of about 419 persons for squire km there are the security block day time is 2 PPL and night is 1PPL there has in plant are day time is 3 and night is 1 in the admin building the capacity concentration is higher in terms of 5 PPL where is in the night it is 2PPL.

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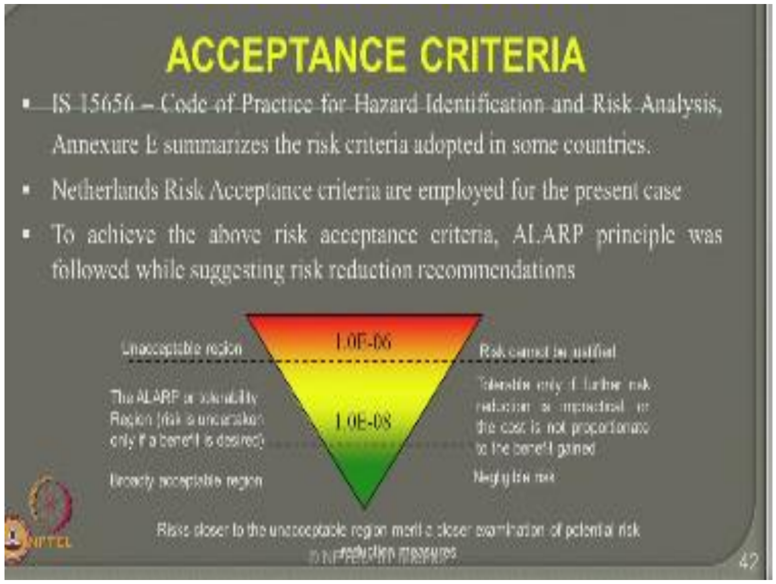

Then we try to mark the risk obtain from the study in terms of acceptance criteria the values which are unacceptable is as high as 110 for – 6 the values which come in all are pigeon or one 10 for -8 the values which are in unacceptable region and then marked the red ban colour, IS 15656 Indian code of practice for hazard identification risk analysis shows in annexure E as a summarizes risk criteria adopted in some countries.

In the present study we are practiced and use Nether land risk acceptable criteria for the group gathering station to achieve the above disk acceptance criteria ALARP principle was employed in the following and the value is plotted as one 10 for -6 as unacceptable region for risk.

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RISK RESULTS

S.No	Scenarios	Combined	
		Individual Risk Per annum	Societal Risk Per annum
1	8" group header pipeline to heater treater 5 mm Leak Size	8.65E-08	1.20E-07
2	25 mm Leak Size	1.83E-06	2.72E-06
3	100 mm Leak Size	[illegible]	6.20E-06
4	Rupture	8.40E-06	8.20E-06
5	Pipeline from heater treater to E/R tank 5 mm Leak Size	9.71E-07	1.07E-06
6	25 mm Leak Size	1.80E-05	2.77E-05
7	100 mm Leak Size	9.10E-05	1.02E-04
8	Rupture	1.36E-04	1.44E-04
9	Pipeline from E/R pumps to jumbo heater treater 5 mm Leak Size	3.24E-08	2.25E-08
10	25 mm Leak Size	2.01E-07	1.44E-07
11	100 mm Leak Size	9.73E-07	6.91E-07
12	Rupture	1.46E-06	8.50E-07
13	Pipeline from jumbo heater treater to T/R tanks 5 mm Leak Size	4.06E-07	6.24E-07
14	25 mm Leak Size	[illegible]	1.29E-06

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Let us know quickly see the risk results taken from the software for the specific problem identify in the case study. For different conditions of 8 inch group header pipeline 8 theta pipeline from a VR tanks and try some jumbo heater theta the in dual risk for Annum this computer societal risk for Annum is also computed and the red mad and values or all showing unacceptable level of risk. For example if the pipeline from heater theta TR tank rapture the 25 on leak or unknown leak or results in whole board rapture the risk can result in unacceptable level for the given plant.

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S.No	Scenarios	Combined	
		Individual Risk Per annum	Societal Risk Per annum
15	100 mm Leak Size	1.15E-05	9.48E-08
16	Rupture	1.09E-04	7.87E-05
18	25 mm Leak Size	1.05E-08	6.58E-07
19	100 mm Leak Size	1.07E-05	6.51E-08
20	Rupture	1.87E-05	2.23E-05
21	Heater treater 10 mm Leak Size	9.66E-06	1.60E-05
22	Catastrophic Rupture	1.28E-07	1.64E-07
23	E/R tanks 10 mm Leak Size	4.80E-05	5.10E-05
24	Catastrophic Rupture	2.75E-06	3.98E-06
25	Jumbo heater treater 10 mm Leak Size	1.10E-06	1.54E-06
26	Catastrophic Rupture	1.44E-07	1.91E-07
27	T/R tanks 10 mm Leak Size	9.26E-06	1.47E-05
28	Catastrophic Rupture	3.1[illegible]E-06	3.92E-06

Similarly for the tankers heater theta VR tankers jumbo heater theta and TR tanks the risk provides are within acceptable values are a lot region high ever for the jumbo heater theta if the result in leak sides or whole board rapture they fall in unacceptable level of risk of the given plant.

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For individual risk you also plotted the risk of concludes which is shown in the figure here the risk levels in terms of key on is shown as 0.001 average here, whereas in terms of pink is 110 $^{-5}$ in terms of Volant it is one 10^{6} whereas the green one is acceptable is one 10-^{7} average here. This of course plotted for different temperature pressure and day and night stability class, based on this we have said that the in novel risk is about 1.36 10^{-4} Per Annum which is resulting from the rather a pipeline from heater theta to emersion the CPN tank which is unacceptable.

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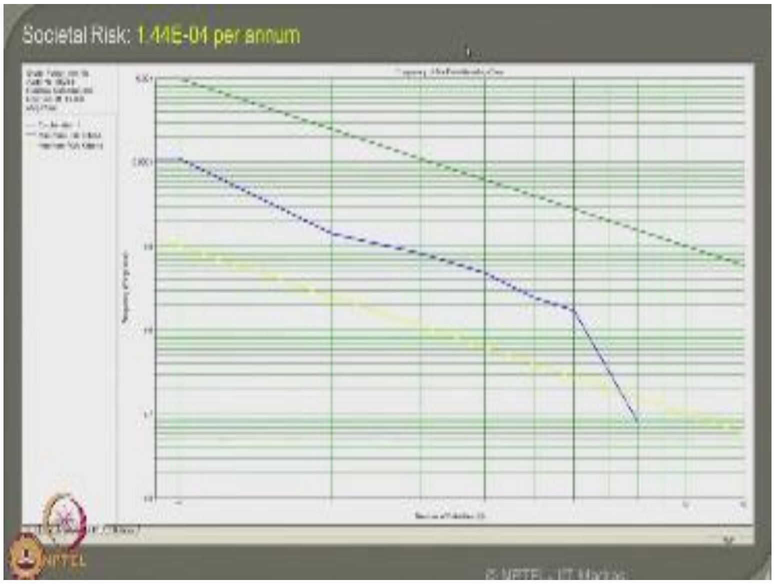

We have also prate a societal risk using FM curve by F stands for frequency average here and N stands for number of fatalities and the one which is blue colour shows the combination of societal individual and the green one shows the maximum risk criteria and the yellow one shows the minimum risk criteria and the combination is within the band however at one specific point is safer coming to minimum expectable. It means the group gathering station does not cause any societal risk as per as the acceptable levels are concern

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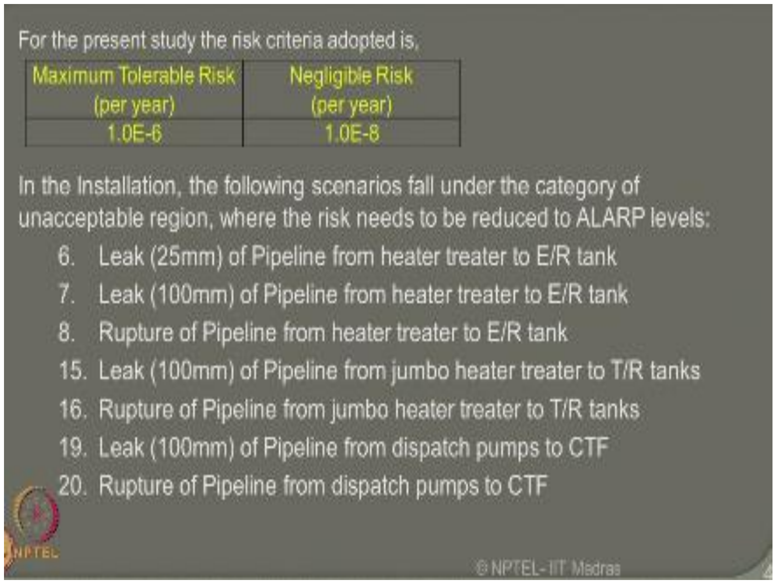

Let us now see maximum tolerable risk and negligible risk for the present study ,the maximum tolerable risk is obtained as 1-10 $^{-6}$per year, whereas negligible is 1-10 $^{-8}$in the current installation the following scenarios fall under the category of un acceptable region where the risk need to be reduced to ALRAP levels 0.25mm leak of the pipe line from heater treater to E/R tank,100mm leak of the pipe line from heater treater to E/R tank rupture of pipe line from heater treater to E/R tank,100 mm leak of the pipe line from jumbo heater treater to T/R tanks rupture of pipe line from jumbo heater treater to T/R tanks 100mm leak of the pipe line from dispatch pump to common tank facility and the whole board rupture of pipeline from dispatch pumps to CTF, these are the scenarios where risk is found out to be unacceptable therefore, risk reduction levels should be applied to bring the risk to adopt levels.

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We also recommended certain risk mitigation methods for the given problem ,the unacceptable risk levels is essentially arising from the amount of flammable material available in the plant to avoid any major catastrophe the material available should be brought down consequence this can be achieved by the implementing various remedial measures for example one of which is trying to reduce to out flow duration which is 30 minutes because you see the recommendation system available in the plant is manual.

Therefore, recommendation to the given plant is now employee semi automatic blocking system to reduce the out flow duration from 30 minutes to 10 minutes or employee automatic blocking system which can further reduce the out flow duration from 10 minutes to 2 minutes. Dear friends wants the suppression system of either automatic or semi automatic is deployed in the plant then the risk can be controlled because the risk level is higher here because the suppression system is manual which can result in 30 minutes exposure of the out flow.

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S.No	Scenarios	Manual System		Semi-Automatic System		Automatic System	
		Individual Risk	Societal Risk	Individual Risk	Societal Risk	Individual Risk	Societal Risk
6	Leak (25mm) of Pipeline from heater treater to E/R tank	1.68E-05	2.77E-05	4.71E-08	6.36E-08	1.66E-09	1.18E-09
7	Leak (100mm) of Pipeline from heater treater to E/R tank	9.10E-05	1.02E-04	3.55E-07	3.12E-07	1.88E-08	1.86E-08
8	Rupture of Pipeline from heater treater to E/R tank	1.36E-04	1.44E-04	2.41E-07	2.41E-07	5.35E-09	4.74E-09
15	Leak (100mm) of Pipeline from jumbo heater treater to T/R tanks	1.15E-05	9.46E-06	5.46E-06	5.15E-08	5.21E-09	4.96E-09
16	Rupture of Pipeline from jumbo heater treater to T/R tanks	1.09E-04	7.87E-05	4.10E-07	3.21E-07	2.11E-08	2.02E-08
19	Leak (100mm) of Pipeline from dispatch pumps to CTF	1.07E-05	6.51E-06	3.83E-08	3.22E-08	2.45E-09	2.46E-09
20	Rupture of Pipeline from dispatch pumps to CTF	1.87E-05	2.23E-05	5.49E-08	4.86E-08	1.18E-09	1.17E-09

Therefore, wants the semi automatic and automatic system are deploy in the given study for the scenarios which are very unacceptable in terms of risk levels we will see the for manual systems these are the unacceptable risk levels which remains still unacceptable even when you go for semi automatic system however when you deploy the automatic system all the risk levels in this scenario becomes acceptable within the adopt levels.

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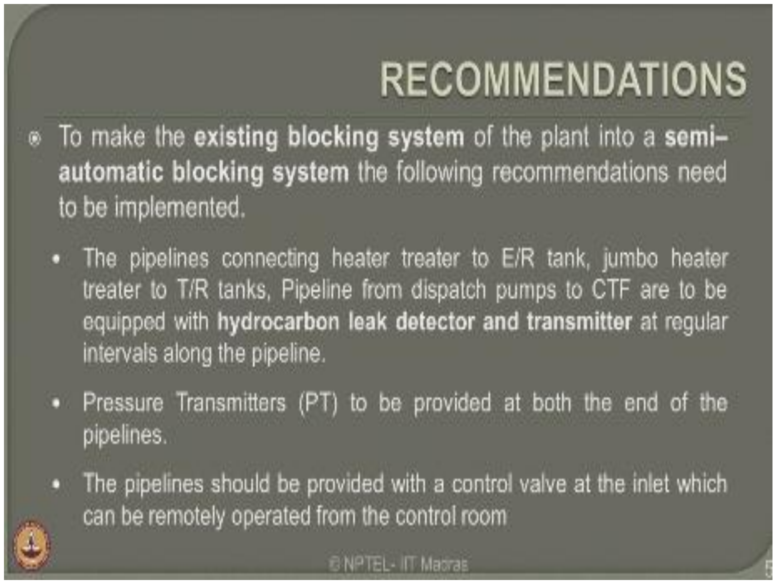

So the final recommendations given to the study are the following to make the existing blocking system of the plant in the semi automatic the following recommendations need to be implemented the pipelines connecting heater treated to E/R tank jumbo heater treater to E/R tank pipeline dispatched pumps to CTF are to equipped with hydrocarbon leak detector and transmitters at regular intervals how long length of the pipeline which is given in the present study.

It is also recommended that pressure transmitters be provided at both ends of the pipelines to notify the pressure variation which can result in leakage pipeline should be also provided with control valves at the inlet which can be remote operated from the control room can be opened or closed depending upon the demand as per the pipeline concept.

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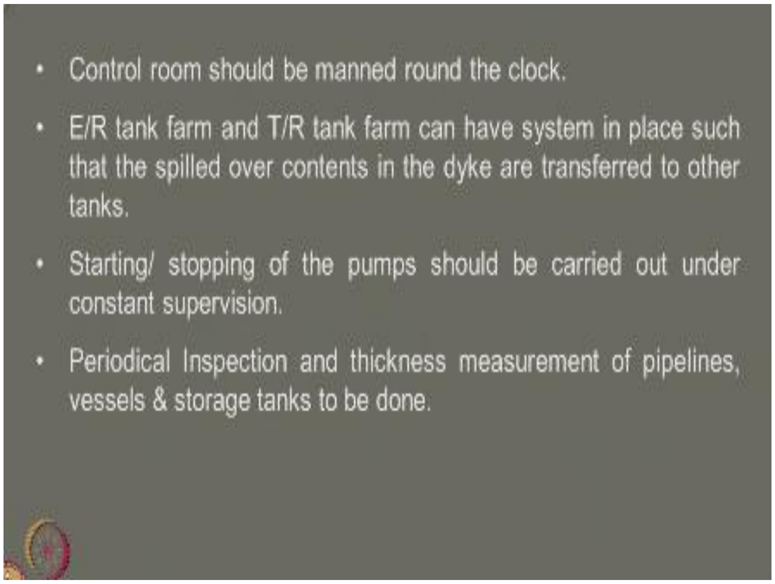

Control room should be manned round a clock E\R tank and the T/R tank can have system in place such that the spilled over contents in the dyke are transferred immediately to other tanks because this can avoid the liquid dispersion in terms of bevy ,starting and stopping of pumps should be carried out under constant supervision periodic inspection and thickness of the pipelines vessels and storage tanks to be done as a strong recommendation for this given problem.

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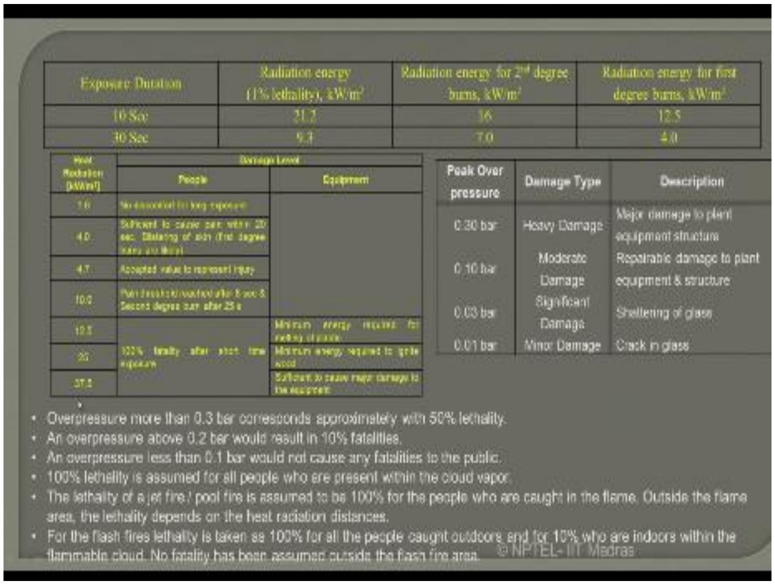

Once it is done then one can see that the expose duration the radiation energy for second degree burns and third degree burns and first degree burns are available here for different heat radiation varying from 1.6to 37.5 that is industrial standard which we have to followed .The peak over pressure which can result in 0.3bar can result in heavy damage type therefore the major damage to the plant equipment structure should be avoided over pressure more than 0.3 bar corresponds approximated at 50%fatilities ,overpressure up to 0.2 bar will result in 10%fetilities and over pressure less then 0.1bar would not cause any fatality to the public.

100%lithelity is assume for all people are present in the cloud vapor the lethality of z fire and poor fire is assumed to be 100 % of people where caught in the flame outside the flame area lethality depends on the heat radiation distances for the flash fire lethality is the present study is taken as 100% for all people caught out door and 10% who are indoors within the flammable clock.

No fatalities assumed outside the flash areas for the given problems so these are some of the data’s which are controlled in the given study which are used based on which risk reduction or recommended in the given plant ,so these example dear friends would have through the light on how to do QRA for the liquid release models various scenarios has been identified in a case study I hope you will follow this, any question you have please post it in twitter thank you very much.

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