Health, Safety and Environmental Management in Offshore and Petroleum Engineering

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Module - 03
Accident modelling, risk assessment and management
Lecture - 11
Chemical risk analysis II

Friend, let us look into the 11th lecture in module 3.

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In lecture 11, we are going to extent the chemical exposure index study as let us say to this Chemical risk analysis. In the last lecture we discussed about the importance of Chemical risk analysis, and what a chemical exposure index can help us to do with, what are the prerequisites of conducting the chemical risk analysis to obtain the chemical exposure index, we also understood the importance of the ERPG guidelines of different levels 1, 2 and 3 and we already understood that in a chemical engineering handbook for all hazardous chemicals different concentration as applicable to ERPG level 1, 2 and 3 are available in the literature. So, we said that one is interested to actually compute the air borne quantity of the chemical, which gets in released in the atmosphere. Let us try to do that now.

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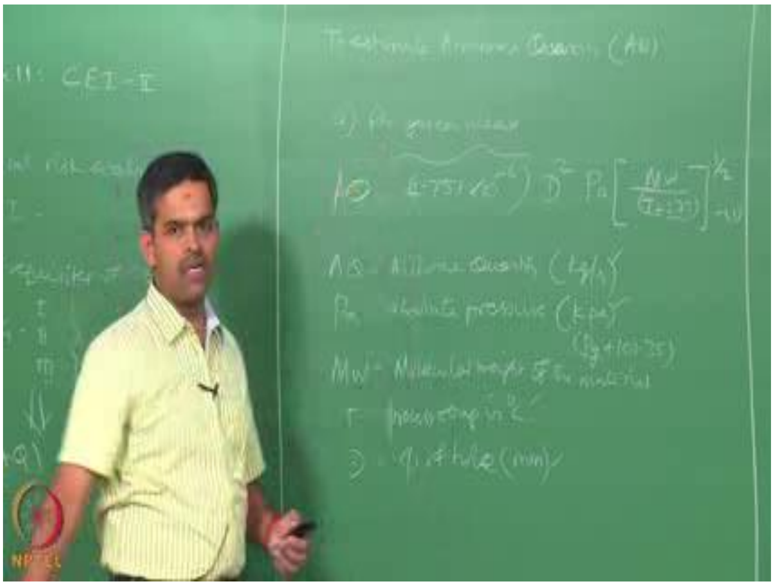

So, to estimate air borne quantity, which we call AQ; obviously, there can be a possibility that the chemical getting released may be in the gaseous state, may be in the liquid state it may become vapour depending upon the flash point temperature. So, let us say for gaseous release AQ is given by 4.751, 10 power minus 6, d square Pa Mw by t whole to the power half equation 1; where AQ is the air borne quantity, which is going to be in kg per second pa is the absolute pressure, which is in kilo Pascal which can be the gage pressure plus 101.35 mw is the molecular weight of the substance of the material, t is the process temperature in degree Celsius I converted that into Kelvin by adding this and of course, capital d is a diameter of the whole in millimetres.

Friends, it is important that we maintain the same unit to compute the air borne quantity because is an empirical relationship, where this constant is calculated depending upon the respective units in the given substitution. So, we compute AQ if you know all these input parameters I can compute AQ, if it is a gaseous release.

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For a liquid release, the steps are slightly tedious. So, step number one called liquid release I have to estimate the total liquid release, which can be given by L is equal to 9.44 10 power minus 7 d square rho 1 square root of 1000 gage pressure by rho 1 plus 9.8 delta h, equation 2 where rho 1 is the density of the liquid in kg per cubic meter at operating temperature, Pg is the gage pressure in kilo Pascal.

For example if you have an open tank, if you have an open tank or open vessel which is open to the atmosphere then Pg is taken as 0, delta h is a height of the liquid column, measured from the release point in meters.

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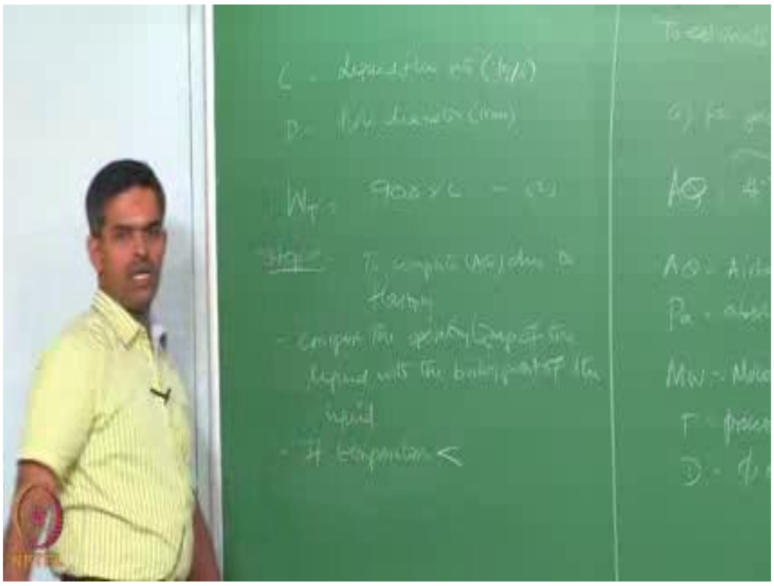

L is expressed as liquid flow rate in. So, many kg per second and of course, d is a whole diameter in millimetres. Once I know the liquid release estimate which is the liquid flow rate from equation 2, they can compute then what we called wt which is 900 into l.

So, step number 2, I want to compute the AQ due to flashing the air borne quantity due to flashing to obtain this compare the operating temperature of the liquid to its normal boiling point.

On comparison, if the temperature is lower than the boiling point.

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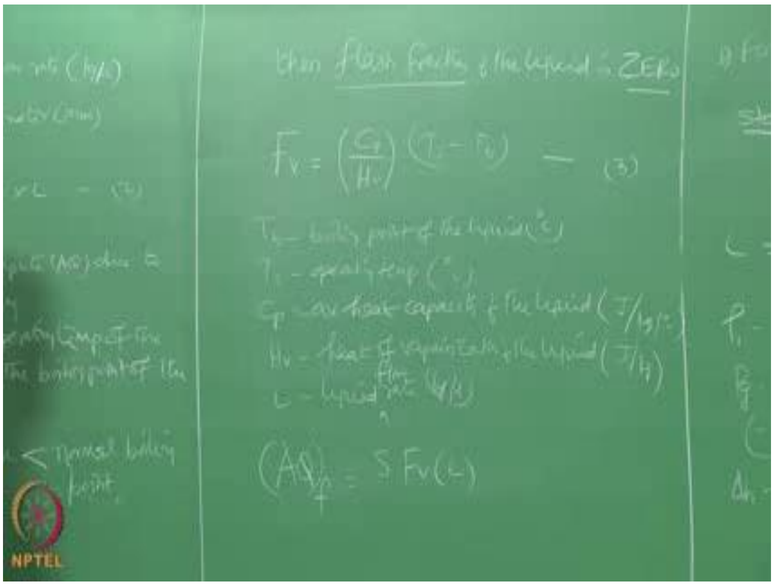

Then the flash fraction of the liquid will be 0, it will not get flash at all otherwise the flash volume Fv is given by Cp by Hv Ts minus Tb equation number 3, where Tb is the boiling point temperature in degree Celsius, Ts is the operating temperature in degree Celsius cp is average heat capacity of the liquid, which is expressed in terms of joule per kg per degree Celsius hv is called heat of vaporization of the liquid, which is given in joules per kg L of course, is the liquid rate in kg per second, liquid flow rate in kg per second.

So, I am interest in working out the air quantity because of flash that is what you are trying to find out the flash fraction, which is given by 5 Fv into L. L is already computed we already know from step number 1 Fv is computed from equation three I can find the air borne quantity of flash fraction from this equation.

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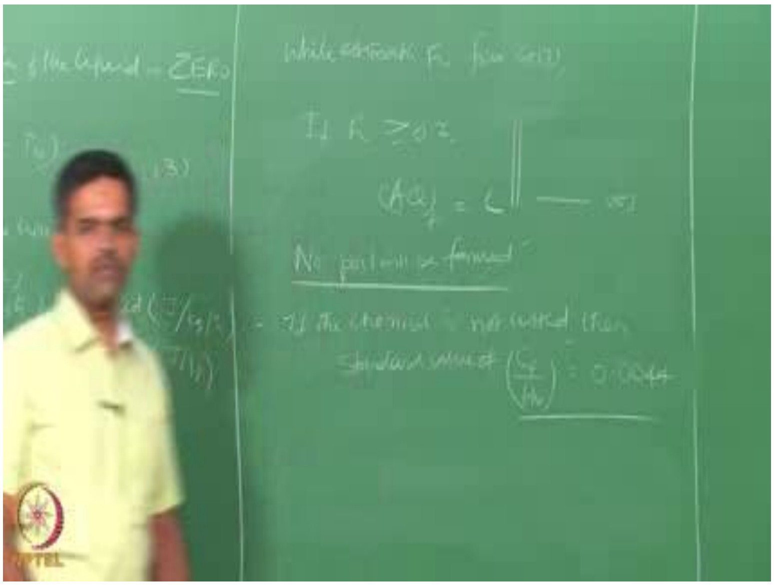

While estimating Fv from equation 3 that is the flash fraction from equation 3, if Fv is more than or equal to 0.2 then, one can say AQ of flash will be straight away equal to the total liquid flow rate itself. So, in that case we can say that no pool will be formed. Let us say this equation number with this condition equation number 5. Interestingly all the chemical properties of the hazards materials like Cp, Hv, Tb, Ts etcetera are to be known. Interestingly if the chemical is not listed, to find any necessary information then in that case standard value of Cp by Hv can be taken as 0.0044.

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As we proceed further as flashing occurs, some liquid will be entrained as droplets. Some of these droplets are quite small and travelled or they could travel over the vapour. While large droplets fall down to the ground and will be collected in a pool. So, large droplets will be collected in a pool, small droplets will travelled along with the vapour. Therefore, if 20 percent material flashes entire stream becomes as to air borne. So, this assumption that if 20 percent of the material, flashes at the operating temperature compared to the boiling point, then it is assumed that entire stream becomes air borne. Therefore, no pool will be formed.

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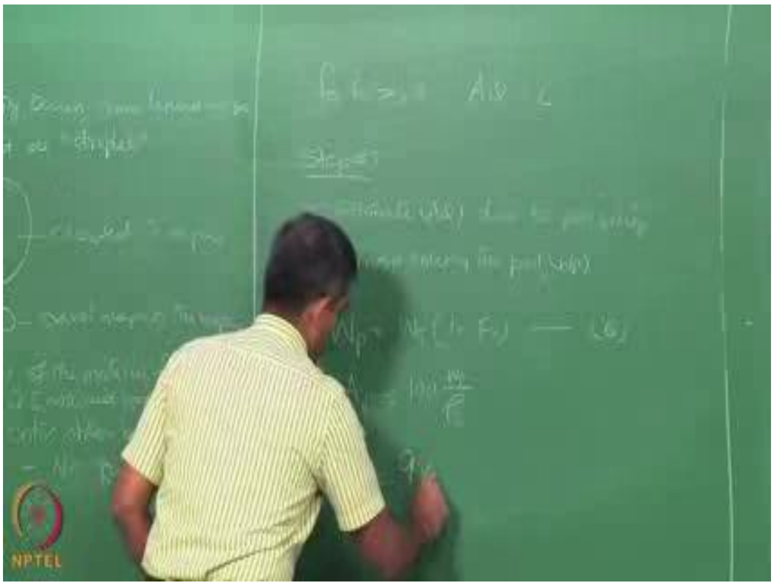

So, that is for Fv greater then equal to 0.21 can say that air borne quantity will be equal to the liquid flow rate and no pool will be formed.

So, step number 3, once the pool is formed I want to estimate air quantity due to pool boiling. So, I would like to work out what is called the total mass entering the pool, Wp which is given by the total mass entering the pool will be Wt into 1 minus Fv equation number 6, and Ap will be given by 100 of Wp by w by rho L and AQp that is the air borne quantity which is coming from the pool boiling will be given by 9, 10 power minus 4, Ap which we compute from here this 0 of 0.95 multiplied by molecular weight into pv by t plus 273 equation number 7.

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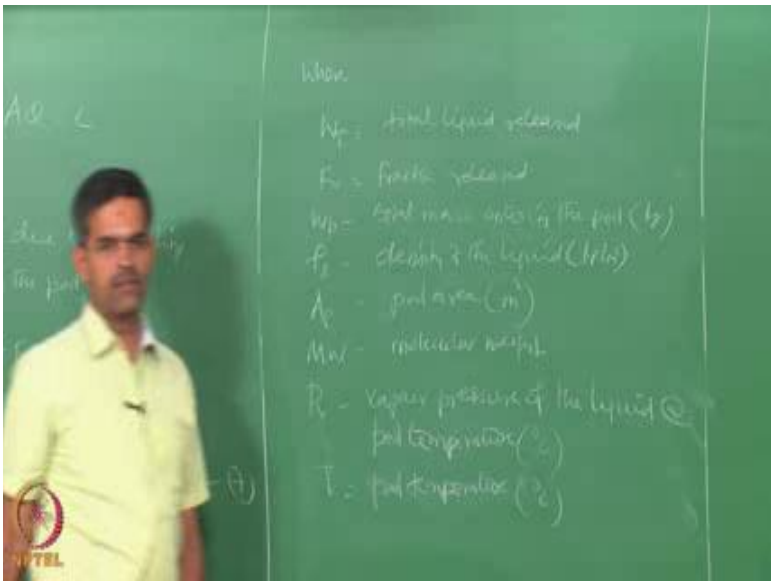

Wt in this equation is the total liquid released Fv of course, is the fraction released, which we already computed, Wp is a total marks entering the pool may be in KGs rho 1 or rho L, is the density of the liquid in kg per cubic meter Ap is the pool area in square meters.

Mw of course, the molecular weight of the material and Pv is the vapour pressure what we have here is a vapour pressure of the liquid at pool temperature. We will generally the pool temperature is in degree Celsius, and t is the pool temperature in again degree

Celsius. So, we can easily find out the air borne quantity of the pool boiling which is coming from here. So, step number 4.

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The total air borne quantity now will be actually equal to air borne quantity which comes from the flash, plus air borne quantity which comes from the pool. Let us call equation number 8, if the air borne quantity what you compute from equation 8, is more than liquid rate L or liquid flow rate L, then air borne quantity is equal to L. It cannot be of course, more than L in any case then one can compute the chemical exposure index.

So, the equation is chemical exposure index given by 655.1 multiplied by the air borne quantity what you computed by the ERPG concentration 2, for the liquid or for the hazardous material. If the CEI computed from our equation exceeds 100, then set the index as 1000 it cannot be more then 100, as I told you while estimating the chemical exposure index one also takes care of the weather conditions, Pascal stability when velocity speed direction propagation etcetera.

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So, CEI calculations assume that, wind speed is about 5 meter per second it also assumes normal weather conditions. ERPG value what we substitute here the equate to be done in milligram per cubic meter because ERPG may be given in other forms of concentration also, ERPG actually nothing, but the concentration which can be sustained by a exposed person for a specific period of 60 minutes, either having no damage either having no irreversible damage either has a reversible damage, but not a fatality that is level 1, 2, and 3 respectively.

So, you have to substitute that value in milligram per cubic meter please look at the concentration available in the tables of chemical engineering handbook, sometimes it can be a different unit that of C ERPG value for a specific concentration in milligram per cubic meter because all these constants are taken care of in this number. So, we are substituting only this exact unit. Now as I said in the beginning one is not interested alone in finding out the exposure index, of course, one is curious to know the exposure index because by this you will know the risk value, but we are not interested and stop here we want to compute the hazard distance. So, to compute hazard distance, hazard distance Hd for a specific concentration can be given by 6551 AQ by specific ERPG value.

Suppose, if you really wanted to know the hazard distance for ERPG level 1, then substitute ERPG level on concentration here. If you want to know of ERPG level to substitute as expect the concentration here and so on. So, you have to accordingly estimate the hazard distance for a specific concentration of course, air borne quantity what we computed from equation 8, will remain unchanged whatever value ERPG you are trying to put.

If the hazard distance exceeds 10,000 meters as computed from equation number 11, then set hazard distance as that is say 10 kilometres that is the maximum distance we can have. It means in general water may be the chemical which is hazards in nature you can always locate the residential units the commercial areas etcetera from away a radius of above 10 kilometres from the central point which is expected to release the chemical. So, after 10 kilometres radius now is locate any plant is going to remain non hazards. So, once you compute the hazard distance for different ERPG concentration, one should done prepare a summary sheet a typical summary sheet is shown in the screen now please look at the data sheet shown in the screen this called chemical exposures summary sheet.

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You have to enter the name of the plant here, Enter the location of the plant indicate the chemical for which you are doing the Ca study also try to enter what the total quantity of this chemical present in the plant. Identify a single largest containment which has got this chemicals stored in the plant note down the temperature operating and the pressure operation of the containment here.

Try to see what scenario we are going to evaluate will talk about the scenario possibly after we complete the discussion here estimate air quantity AQ release rate may be in kg per second or may be in different units counts by minute we are interested in kg per second, all equations gave you on the blackboard, where only and kg per second. So, estimate the air borne quantity in kg per second either it is a liquid or a gas. Try to enter this we have the respective equations available with me then calculate the chemical exposure index which I have given you in equation 10 on the blackboard here equation 10 use this and estimate CEI.

Please understand CEI index is always related to concentration of ERPG 2 level that is very, very important. So, enter the CEI index here of course, for a given chemical concentration for a given chemical in the plant enter the concentration values of ERPG 1, 2 and 3 in milligram a cubic meter and using equation eleven the corresponding ERPG concentration, substitute for that and get the hazard distance in meters and enter the hazard distance in meters here then based upon this can always give a recommendation? What we call dou property line. So, please recommend what could be the distance in meters beyond which public can be located? Other in company can be located, non company business can be located. So, interestingly we gone to fill up this and then assess what could be the consequence on these if the distances are closer than hazard distances for a specific concentration arrived from this equation.

So, this summary sheet will tell you completely, how to estimate a chemical exposure index how to estimate the hazard distances and what to be the consequence of public property etcetera lying within this hazard distance for a specific concentration of ERPG level which is available in the chemic in hand book for all hazardous substances. You must also say who has prepared the report, who has reviewed the report what was the date at which you reviews the site and what additional recommendations you made under what capacity you made. So, this report is a legal document, which is stocked and stored in the industry. So, friends after preparing chemical exposure index, one need to prepare the mitigation check list.

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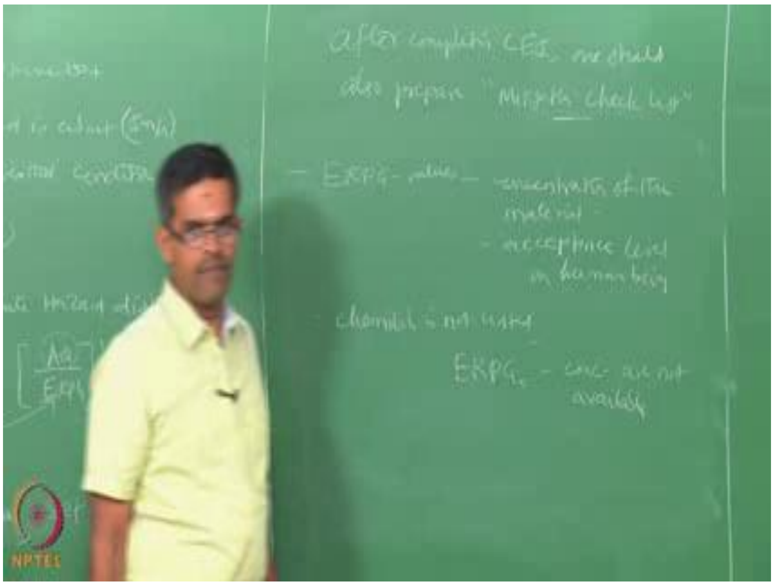

So, after completing chemical exposure index one should also prepare mitigation check list. A typical mitigation check lists can be seen on the screen now.

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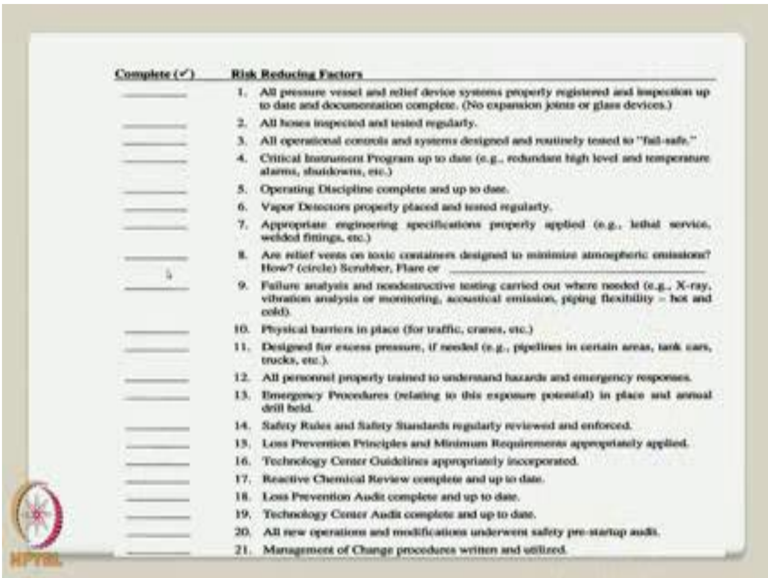

Complete (✓)	Risk Reducing Factors
______	1. All pressure vessel and relief device systems properly registered and inspection up to date and documentation complete. (No expansion joints or glass devices.)
______	2. All hoses inspected and tested regularly.
______	3. All operational controls and systems designed and routinely tested to "fail-safe."
______	4. Critical Instrument Program up to date (e.g., redundant high level and temperature alarms, shutdowns, etc.)
______	5. Operating Discipline complete and up to date.
______	6. Vapor Detectors properly placed and tested regularly.
______	7. Appropriate engineering specifications properly applied (e.g., lethal service, welded fittings, etc.)
______	8. Are relief vents on toxic containers designed to minimize atmospheric emissions? How? (circle) Scrubber, Flare or ______
______	9. Failure analysis and nondestructive testing carried out where needed (e.g., X-ray, vibration analysis or monitoring, acoustical emission, piping flexibility – hot and cold).
______	10. Physical barriers in place (for traffic, cranes, etc.)
______	11. Designed for excess pressure, if needed (e.g., pipelines in certain areas, tank cars, trucks, etc.).
______	12. All personnel properly trained to understand hazards and emergency responses.
______	13. Emergency Procedures (relating to this exposure potential) in place and annual drill held.
______	14. Safety Rules and Safety Standards regularly reviewed and enforced.
______	15. Loss Prevention Principles and Minimum Requirements appropriately applied.
______	16. Technology Center Guidelines appropriately incorporated.
______	17. Reactive Chemical Review complete and up to date.
______	18. Loss Prevention Audit complete and up to date.
______	19. Technology Center Audit complete and up to date.
______	20. All new operations and modifications underwent safety pre-startup audit.
______	21. Management of Change procedures written and utilized.

Please look at all possible risk reducing factors like all pressure vessels and relief this system devices are properly registered, all houses inspected, all operational controls and systems designed and routinely tested for no failure critical instrumentation program is up to date, operating discipline complete and up to date, vapour detectors installed and working properly appropriate engineering specifications applied properly, relief vents in toxic containers are designed properly etcetera. So, look at all these risk reducing factors and keep on preparing a check list whether they have been done or not done maybe yes or no only, maybe a tick mark or a cross mark. So, based upon this mitigation check list one will have fairly an idea, which is given along with the chemical exposure index sheet. So, one will give get an idea about the risk in message, because of the accident release of the chemical from the plant on to the environment.

Now, there are further more discussions about this ERPG values because ERPG values actually talk about the concentration of the chemical or the liquid or concentration of the material in terms of its acceptance level on human. If the established ERPG level are not available maybe the chemical is not listed and ERPG level, ERPG for level 1, 2 and 3 concentrations are let us say not available. In that case what do you do because without knowing the ERPG concentration you can neither calculates the hazard distance nor the chemical exposure index because, you need the value there may be certain chemicals certain mixture certain composition whose ERPG level values of concentration may not be given in the table listed in the table all in the hand book in that case what do you do?

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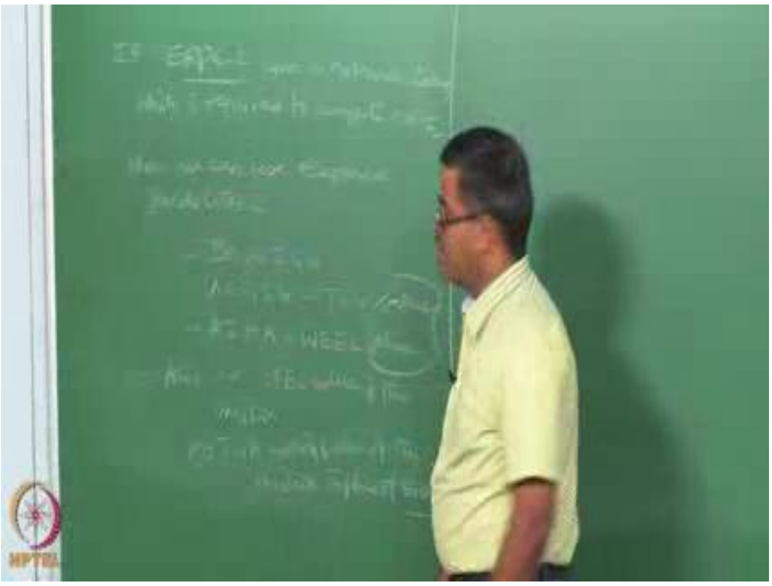

Let see for example, if ERPG 2, Concentration is not available, which is required to compute the chemical exposure index because please understand friends chemical exposure index is computed based only on ERPG 2 level concentration.

Then one can use the exposure guidelines given by various international agencies recommended by let say dou IGH American Society or Congress of Industrial Hygienists they have given the TLV limits there are showed value limits one can also look at American Industrial Hygiene Association, where they have given WEEL values. So, one can look at these values and use them as an alternate substitution for ERPG 2 for a mixture which not available. One can also use short term exposure limit that is STEL values of the mixture or time weighted average Ceiling value of the mixture in place of ERPG 2. So, that is as for the discussion on ERPG 2, is concerned which is required to compute the chemical exposure index.

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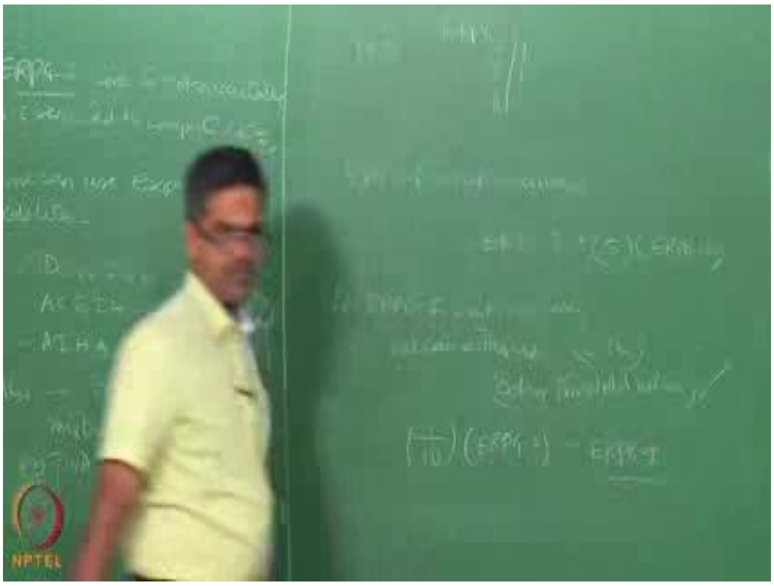

Now, to compute the hazard distances you may require ERPG of all the levels, ERPG 1, 2 and 3 all will be required because hazard distance can be estimated for all concentration. So, if ERPG 3 is not available or is not listed for the mixture in the table then one can assume ERPG 3 as 5 times of ERPG 2. If ERPG 1 is not available or not listed in the table then one can either find out the, one can either use Odor Threshold Value OTV, that is called Odor threshold value available in the literature in phrase of ERPG 1 or 1 can use, 1 by tenth of ERPG two as ERPG 1. In case they are not available as being explained and understood, we all know that chemical exposure index is computed for a specific scenario.

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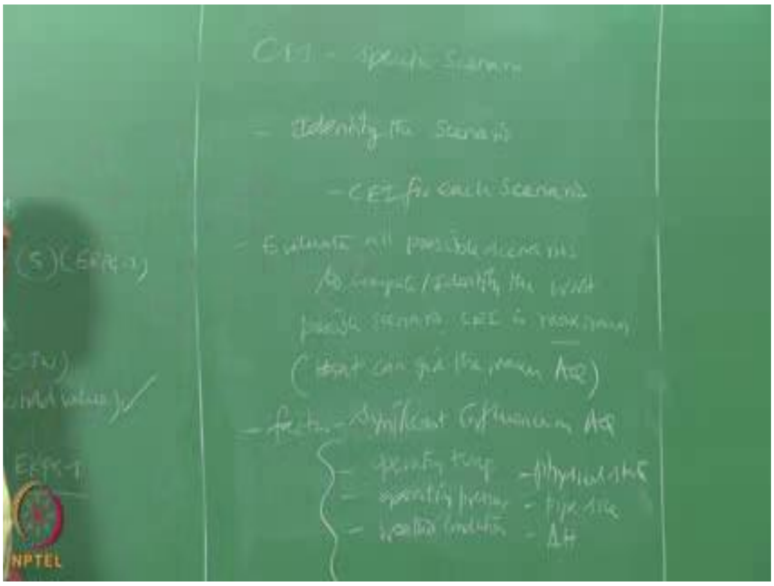

So, the Fomo job in a given plant is to identify the scenario, identify the scenario or if you can identify more than one scenario you must compute CEI for each scenario. So, the purpose is to determine which process piping is equipment as a greatest potential for release of significant quantity of acutely toxic chemicals. So, one should evaluate all possible scenarios to compute or to identify the worst possible scenario, whose CEI is maximum or on the other hand which can give, that can give the maximum air borne quantity that is what it is all process condition such as temperature pressure, physical state, pipe size, should be considered.

So, that they have a significant impact on the air borne release rates. So, please understand the factors which will have significant impact or significant influence on estimating air borne quantity could be temperature, that is operating temperature, operating pressure then weather conditions, then physical state of the chemical, then of course, the pipe size height of release all factors will influence significantly the air borne quantity which in turned influences the chemical exposure index value what you obtain.

Interestingly friends the whole exercise of CEI amounts to identifying various scenarios. So, in a given process plant, you must try to identify various scenarios for each scenarios we must obtain the chemical exposure index, then try to identify the worst possible scenario whose CEI index is the maximum or alternatively the scenario which will give me maximum air borne quantity. So, in the next class will take up examples and identify scenarios workout CEI value and AQ values for all the scenarios and then will compare the scenarios and say amongst identified scenarios which are having the maximum air borne quantity or the maximum CEI index.

So, in this lecture we learned how to actually do a chemical exposure analysis, how to estimate chemical exposure index which is given by the dows method, we also understood how the gas and liquid concentrations can be equally handled by different equations which are empirical in value. What are the factors that can influence the hazard distances what are the factors that can influence the chemical exposure index or AQ value, and what are the factors which can influence the ERPG values which are available in the literature, if ERPG values are not available what are the alternative values for ERPG 1, 2 and 3 to estimate the appropriate hazard distances. So, ultimately chemical exposure index will give me an equal hazard distance beyond which, if the public is placed will have no effect even though the chemical maybe release and any specific rate and remain as air borne.

Thank you very much.