Health, Safety and Environmental Management in Petroleum and offshore Engineering

Prof. SrinivasanChandrasekaran

Department of Ocean Engineering

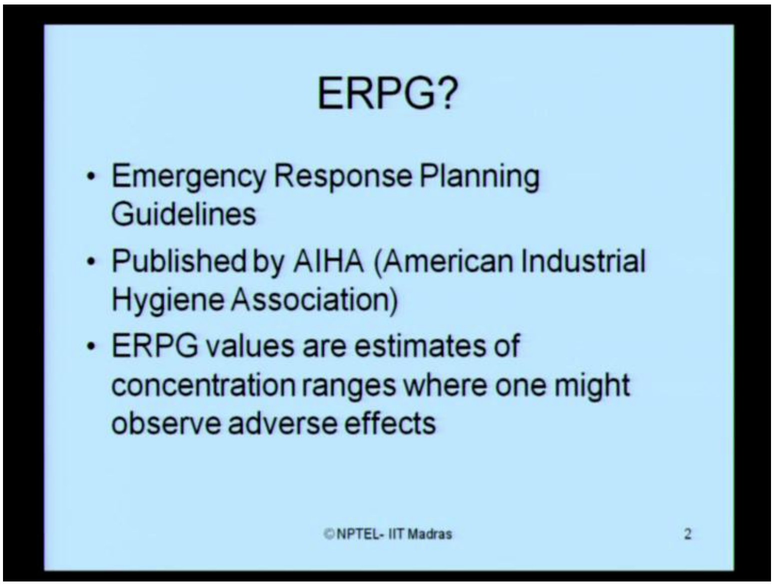
Indian Institute of Technology, Madras

Module No. #03

Lecture No. #03

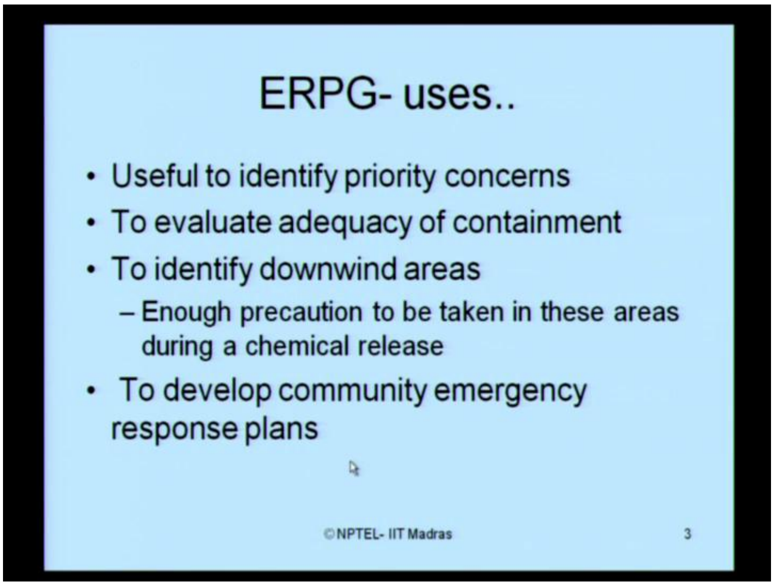
Chemical exposure index (CEI)

(Refer Slide Time: 00:16)



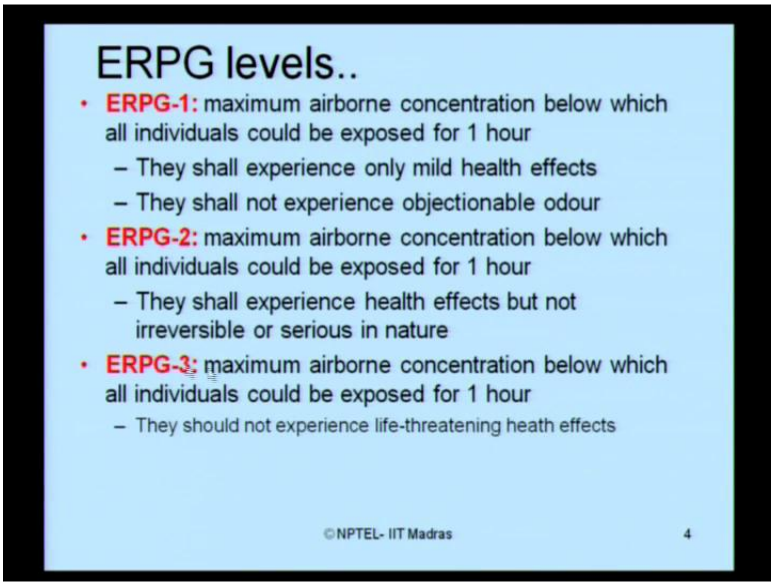
So, we continue to discuss on chemical exposure index which is chemical risk analysis in that connection we discussed about what we called as ERPG- Emergency response planning guidelines. Basically it is the guideline published by American industrial hygiene association. ERPG values are actually estimates of concentration ranges where one might observe adverse effects. Basically ERPG will ultimately give you what I called as hazard distance.So, basically these are values of concentration ranges which one might observe very severe adverse effects on human health.

(Refer Slide Time: 00:52)



What are the natural uses of ERPG? They are useful actually to identify priority concernsrelated to safety in any process industries. To evaluate adequacy of containment of the process industry; to identify downwind areas therefore, you can take enough precaution in these areas during any such toxic release of the chemical. Also to develop what we call as community emergency response plans.

(Refer Slide Time: 01:28)

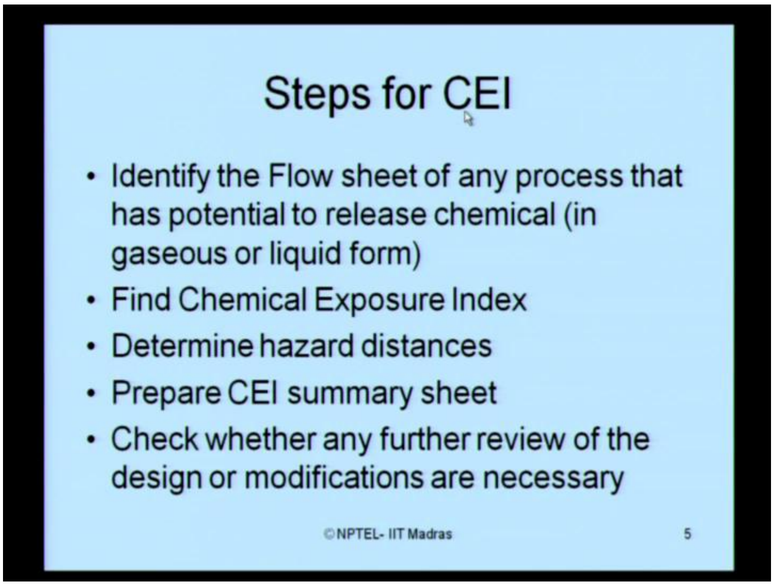


ERPG levels actually have got distinctly three values, what we call as ERPG-1, 2 and 3. There are three levels by which the ERPG can be specified. Maximum airborne concentration below which all individuals could be exposed up to a period of 1 hour.So, it is the maximum airborne concentration of a chemical below which every individual can beexposed up to a maximum period of 1 hour provided these individuals shall experience very mild health effects.They shall not experience even an objectionable odour. So, it is a very mild concentration of chemical, which every individual can be exposed. Remember, individual means not the plant operators; any public living around the area of the industry also isconsidered as individuals only. The all individuals who can be exposed to a maximum duration of 1 hour without experiencing, even an objectionable odour due to the chemical release, as well as they do not result in any health effects.If at all they have they have only very mild effects like for example, eye irritation etcetera.

If you have any such kind of airborne concentration then you call that concentration levelas ERPG level one. Subsequently, if you have an airborne concentration below which you are exposing every individual to a maximum period of one hour, but they shall experience health effects, but not irreversible or serious in nature. So, the person or the people who will be exposed such concentration - airborne concentration, for a maximum period of one hour will experience certain health effects, but those health effects will not be serious in nature. So, if you have any such airborne concentration to themaximum value which will result not in an irreversible effect on human health, but some health effects will be caused when they are exposed to a maximum period of one hour we call that concentration level as ERPG-2.

Now, ERPG-3 is the maximum airborne concentration below which all individual can be still exposed for a period of one hour, but without experiencing any life threatening health effects. So, they will have adverse health effects; some of them may become irreversible as well, but it should not end up in fatal. They should not die basically. So, if they not experience such kind of life threatening health effects, and if they are exposed to such maximum airborne concentration due to a chemical release for a maximum period of one hour then we call that ERPG level as ERPG-3.

(Refer Slide Time: 04:44)



Once you define the different levels of exposure of maximum airborne concentration resulting from a chemical release then let us try to understand the steps involved in what I call as chemical exposure index study.In chemical exposureindex study, try to first identify the flow sheet of any process for which you are doing the CEI investigation.Look at that process and try to understand the potential to release a chemical; whether the chemical to be released from the industry will be in a gaseous form or a liquid state; if at all it will be released, what will be the flow process where that release could occur from the containment, from the process line etcetera.

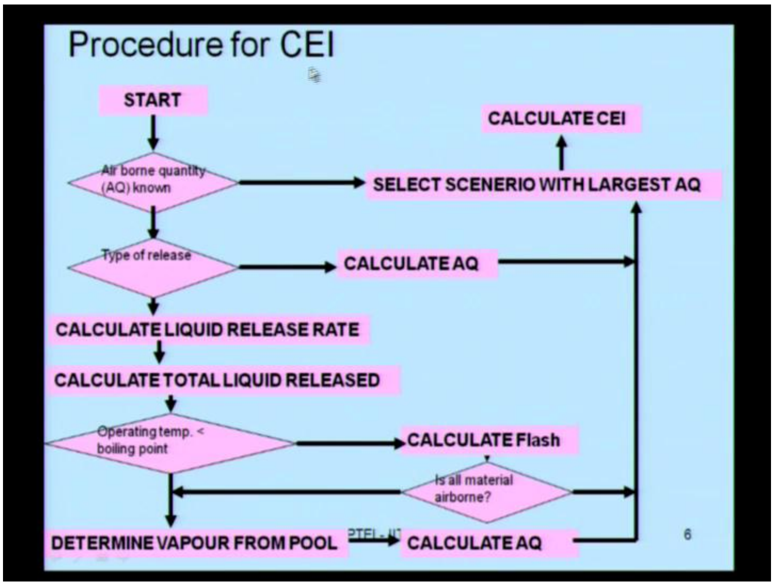
What will be the people in operation in such chemical plants, what will be the population of the public in the real vicinity of this chemical industry?All data should be available to me before I start a plan CEI study on any chemical release problem. Once I have thatsubsequently I determine what I call as chemical exposure index. So, I will get a number which will be a quantitative number which is converting the toxic dispersion effect of chemical on human health.

Remember health effect is a subjective value; toxic release is again a subjective value, but we are trying to convert these two aspects on a mathematical figure by giving a number using some mathematical technique. I will detail explain this procedure in couple of lectures, we will do at least three examples to really make you to understand how can I perform chemical exposure index study.

Ladies and gentlemen, remember this is one of the important landmark study in risk analysis of chemical process industries, whichis very common in oil and gas industry. So, kindly follow this step by step thoroughly. If you of course have difficulties, you can always send a feedback to the speaker or the author at NP-TEL, IIT Madras.

So, find a chemical exposure index. Ultimately determine what we call as hazard distances. I think you can get a clue from this terminology itself, I am trying to work out what I called as safe distance, beyond which my public should live with respect to the chemical industry, which is likely having a potential of release of chemical which is hazardous to the public. I determine that distance which I call as hazard distance and that distance is to be determined based on a specific problem or a number which I call as a chemical exposure index value. Then I prepare what I call as the CEI summary sheet then check whetherany further review of the design or modifications are necessary. So, these are the broad steps involved in doing a CEI index study.

(Refer Slide Time: 08:11)



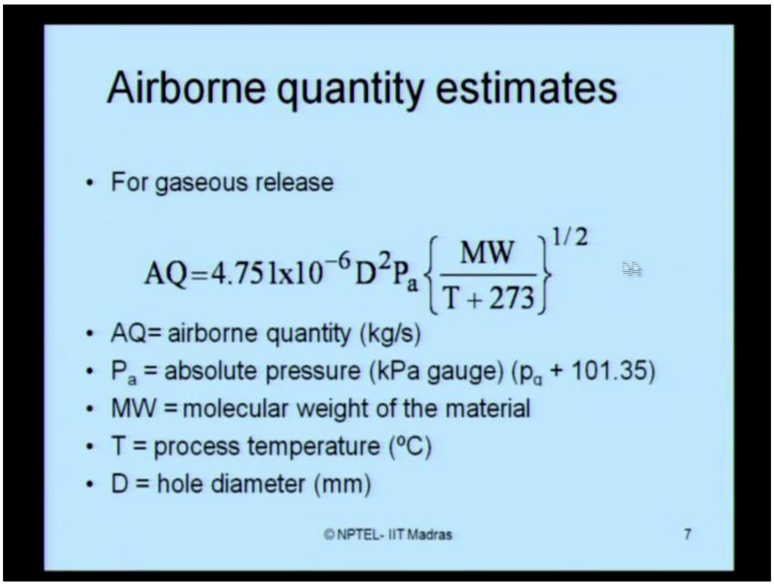
Let us see a detailed procedure how to do a chemical exposure index analysis. Remember this is a very common model which is used for chemical risk analysis for dispersion models.For example, I start doing a chemical exposure index study. I first calculate what I call airborne quantity AQ. If I know the AQ value readymade on hand then select the scenario with the largest AQ and calculate CEI.

Now, you may wonder how do I compute the airborne quantity for a specific chemical to be released or expected to be released in environment.I am coming to that equations later, but if you have got many such scenarios manysuch hazardous situations which will release chemicals in air then select the scenario which is having the largest AQ and compute chemical exposure index number based on the largest AQ.I will come to get the equations how to get this.

Suppose, if you do not have an airborne quantity then identify the type of release in your case.If you know the type of release for each type of release compute the AQ value. For a liquid release rate, for a liquid let us say for example, estimate the liquid release rate and calculate the total liquid released based on this; also identify the operating temperature, if the operating temperature is less than the boiling point of the specific chemical then calculatewhat they call as flash or determine the vapour pool then also check whether is all material completely airborne.If it is yes then from the vapour pool compute the AQ and check for different scenario different AQ, and select the scenario with the largest AQ and try to find chemical exposure index. So, this is a very simple flow sheet which will tell you the different steps involved in doing a chemical exposure index analysis.

So ultimately for finding out chemical exposure index, I require what I call airborne quantity. Airborne quantity,of course, depends on what is the type of release you are talking about. If it is a vapour release or a liquid release even for a liquid release whether the operating temperature is below boiling point or greater than boiling point;all these issues should be understood in advance before I do a chemical exposure index analysis for a specific toxic release.

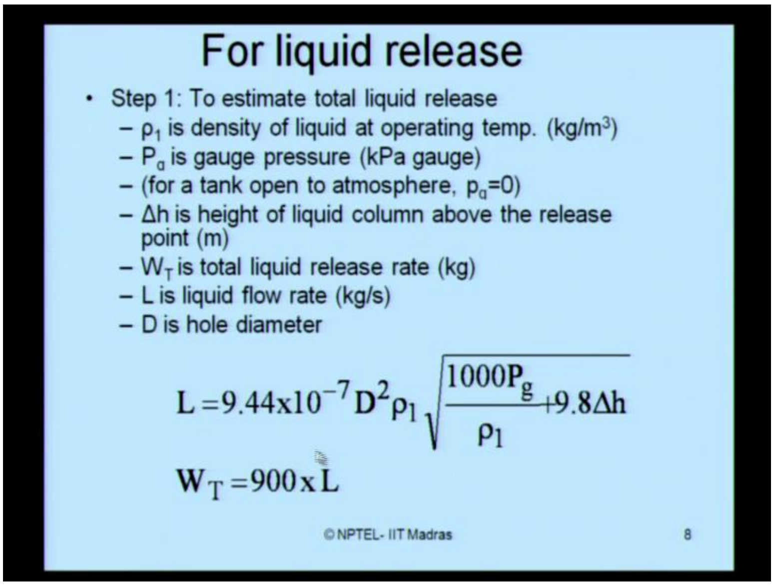
(Refer Slide Time: 11:08)



Now, the question comes airborne quantity, how to estimate the airborne quantity? If it is a gaseous release, let us check how to do that. I have a very simple equation which is shown here AQ is given by this relationship,where AQ is available in kilo gram per second; P a is an absolute pressure at which the system is operatingwhich is kilo P a in gauge pressure orP a plus 101.35. MW is a molecular weight of the material, and T is the process temperature in degree Celsius. Now I am talking about a gases released, the gas will be release from a specificpuncture of a pipe or a puncture in containment,Iam looking for the whole diameter in millimeters.

So, once I have these data with me in their respective units, I substitute them here to find AQ in kilo gram per second. It means, somuch kilogram of the chemical will be released in the gaseous format per second - that is what I will get from this equation.

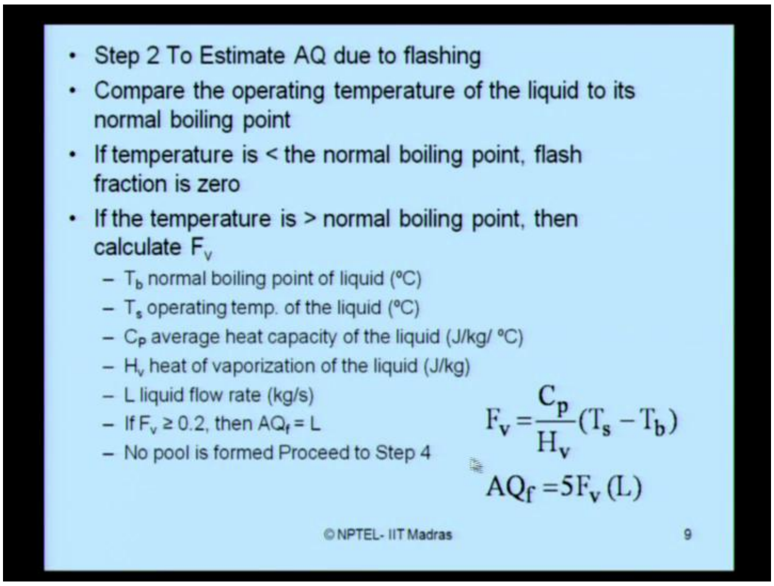
(Refer Slide Time: 12:29)



Suppose it is a liquid release then try to understand, what is the density of the liquid at operating temperature? Try to know what is the gauge pressure at which it is operating,for example, if it is you are dealing with the tank open to the atmosphere there you can consider this as zero. Determine delta h which is the height of the liquid column above the release, point for example, you have a big container or a containment, the containment has a specificheight delta height of the column and the release is happening at the bottom try to find delta h in meters. W T is a total liquid release rate which is given in kilo gram and L will be the liquid flow rate. The D is again the hole diameter through which the liquid is getting released.

Now, I can easily find the liquid flow rate first as given by this equation, where D is the hole diameter, rho 1 is the density of the liquid at operating temperature, P g is a gauge pressure, and delta h is the height of liquid column above the release in meters. Sofrom this equation, I will get the liquid flow rate in kilo gram per second; from the liquid flow rate I obtain what is called total liquid release rate in only kilo gram by simply multiplying with 900.

(Refer Slide Time: 14:00)

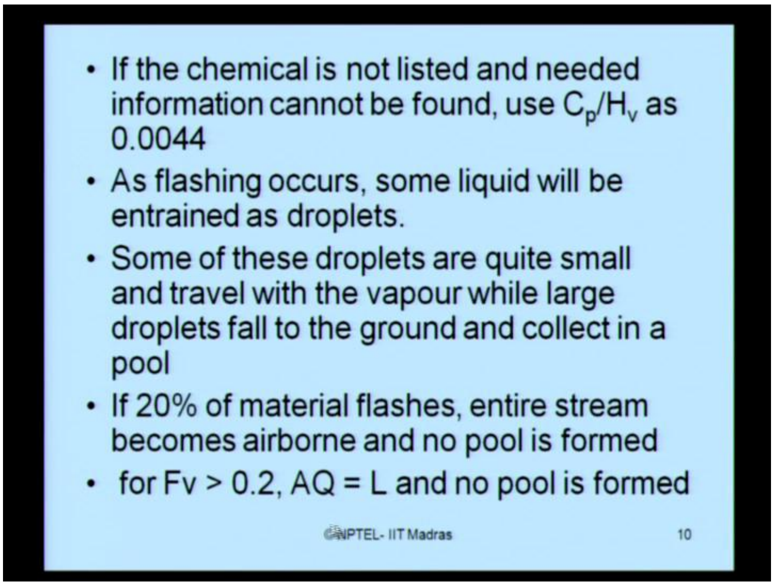


Once I get this value,now I will try to estimate the airborne quantity due to flashing. Remember the flow chart which we discussed flashing will occur only when the boiling temperature operating temperature is to be compared with normal boiling point. If the temperature is less than the normal boiling point flash fraction will be zero. If the operating temperature is more than the normal boiling point than part of the liquid will become vaporized what we call as a flash fraction.

I want to find that specific volume because the operating temperature is higher than the normal boiling point of that chemical. If my T b is the normal boiling point of the liquid and T s is the operating temperature and T s is greater than T b. So, that I get the volume of flash fraction C p is average heat capacity of the liquid in joules per kg per degreeCelsius; H v is the heat of vaporization of the liquid in joules per kilo gram, and L is a liquid flow rate which you have obtained from the previous equation, and which F v will now given by this equation which is a flash fraction which is given by C p by H v T s minus T b.

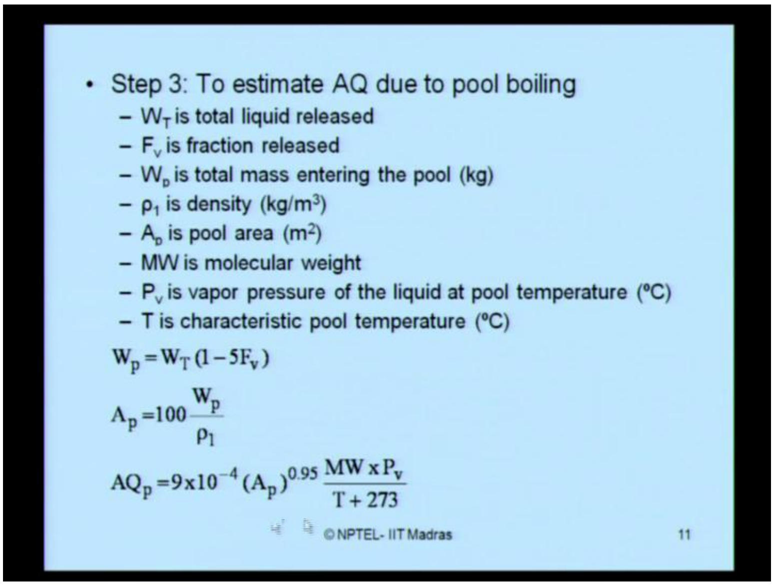
C p is the average heat capacity H v is heat of vaporization and T s and T b are operating temperature and boiling temperature and this figure will be positive if you would not have a flash for example, once you obtain the flash fraction the air Q f that is air quantity of flash will be given as five times of this into L. If this F v is greater than 0.2 then AQ f is considered simply as L only.In that situation no pool will be formed and we can proceed to step number fouror else pool will be formed.

(Refer Slide Time: 16:02)



Now, the question is if the chemical is not listed and needed information cannot be found from a standard chemical table then use C p by H v as a previous equation as a constant as 0.0044. Now as flashing occurs, some liquid will be entrained as droplets. Some of these droplets are quite small and travel with the vapour while large droplets fall to the ground and collect in a pool. So, we would like to find what is a pool formation? If 20 percent of the material flashes, the entire stream becomes airborne and no pool is formed;that is a general assumption what we make in this c a calculation.Therefore, if F v is more than 0.2, the airborne quantity is taken straight as a liquid and no pool will be formed.

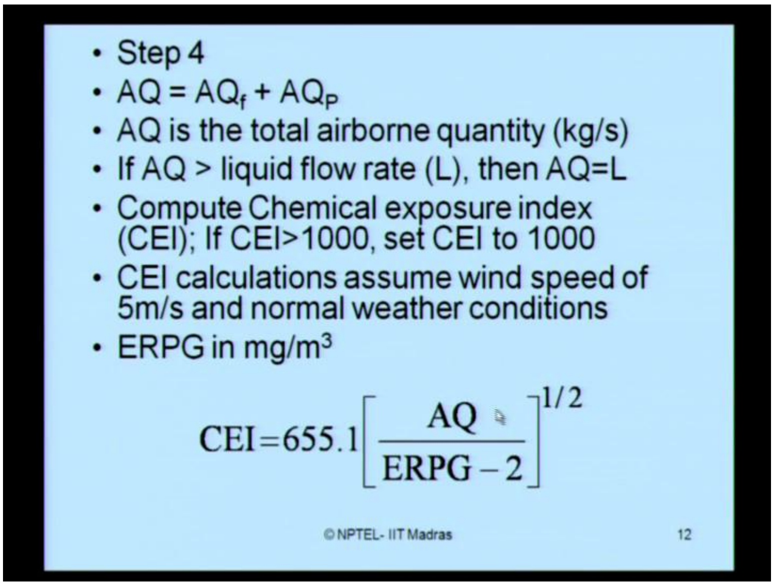
(Refer Slide Time: 16:57)



If it is not so,try to find,what is air quantity due to pool boiling? If W t is a total liquid released and F v is the fraction released which you saw in the previous equation, W p is the total mass entering the pool, rho 1 is the density in kilo gram per cubic meter, and A p is the pool area, and MW is the molecular weight then P v is the vapor pressure of the liquid of the pool temperature expressed in degree Celsius at the pool temperature of degree Celsius, and T is a characteristic pool temperature in degree Celsius then AQ pwhich is the area airborne quantity due to pool boiling will be given by this equation. Where MV is the molecular weight, P v is the vapor pressure; T is the temperature in the characteristic pool temperature in degree Celsius.I can also find W p from this equation and A p which I got to use from this equationwhich is the function of W p and rho1.

Therefore ladies and gentlemen, I can find airborne quantity due to pool boiling or airborne quantity due to flash only if it is a liquid released from this previous equation as I discussed.

(Refer Slide Time: 18:19)

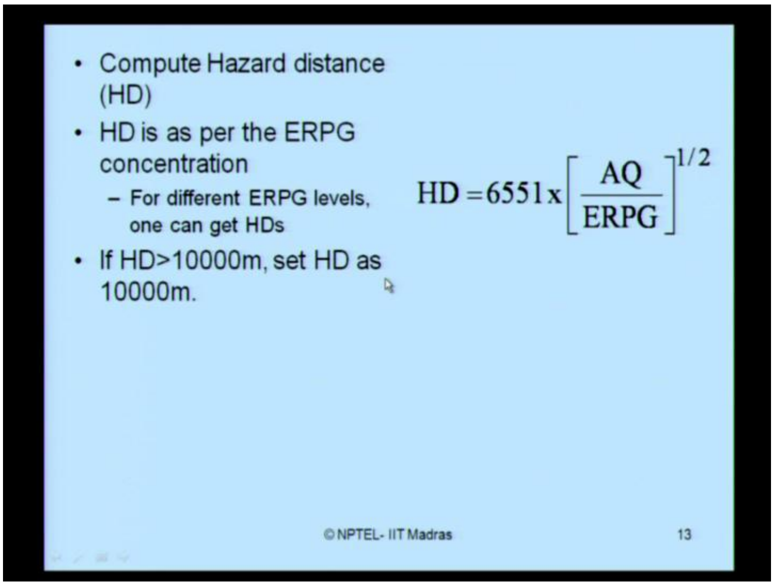


Subsequently in step number four, I try to find what is AQ f and AQ p as a sum. This is airborne quantity due to flash fraction; this is airborne quantity due to pool formation. The total airborne quantity of liquid released will be given by a summation of these two value, which is given in kilogram per second. If the airborne quantity is more than the liquid flow rate what I calculated earlier then I simply say airborne quantity will be exactly equal to the liquid flow rate which I estimated.

Then compute the chemical exposure index CEI.If CEI is greater than 1000, set CEI to 1000. The CEI calculations actually assume a normal wind speed of 5 meter per second and a normal weather condition present in the plant. In CEI calculation, you are using ERPG in somany mg per cubic meter. Suppose if you have this ERPG in a different concentration in ppm, we have already given you equation as to convert these into ppm as well depending upon the molecular weight of the chemical being exposed.

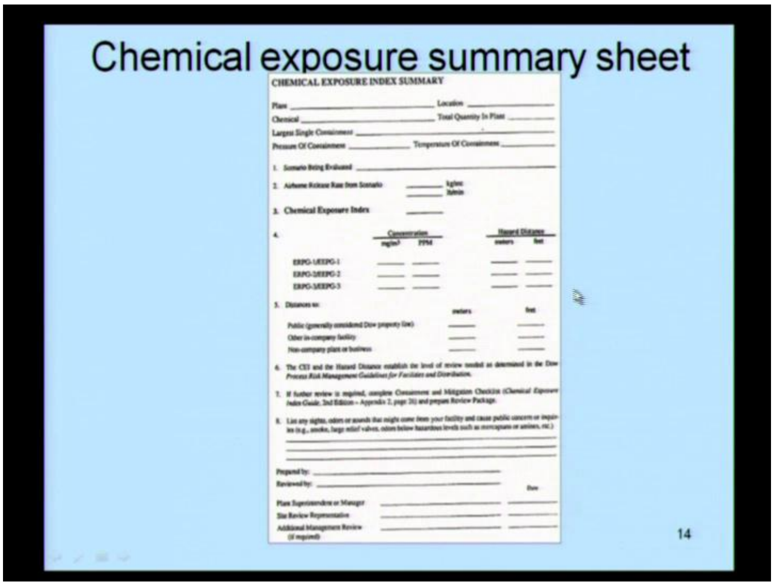
So, CEI is given by a simple equation which is 655.1 multiplied by the ratio of AQ by ERPG-2 square root of this value. Ladies and gentlemen, it is not ERPG minus two; it is ERPG second level; recollect that ERPG are of three levels ERPG-1, ERPG-2, ERPG-3. AQ can be airborne quantity of a gas or a liquid which is got to be appropriatelyobtained using the previous equation. So, get the ratio of these two and find the CEI using this equation.

(Refer Slide Time: 20:10)



Based upon the obtained CEI value, try to find what we call as hazard distance. The hazard distance is actually given by a simple relationship what you get here. Now the hazard distance is as per a specific ERPG value,for example, if you substitute here ERPG-1, you get hazard distance for ERPG level one. Recollect ERPG level one, level two and level three or addressing basically different kinds of effect of chemical release on human health. So, depending upon a specific chemical ERPG values are available in the table, pick up those ERPG values and for each respective ERPG valueobtain what I call as hazard distance. If the hazard distance what you get from this equation exceeds 10000 then set hazard distance as 10000 meters or 10 kilometers.

(Refer Slide Time: 21:15)



Once you find the ERPG based on ERPG’s different hazard distances, try to fill up what we call chemical exposure summary sheet. The chemical exposure summary sheet is a very interesting format in a comprehensive form which is to be filled up to make people to understand the hazard distances of different type of release what you have estimated. Let us spend some time in understanding this specific report.

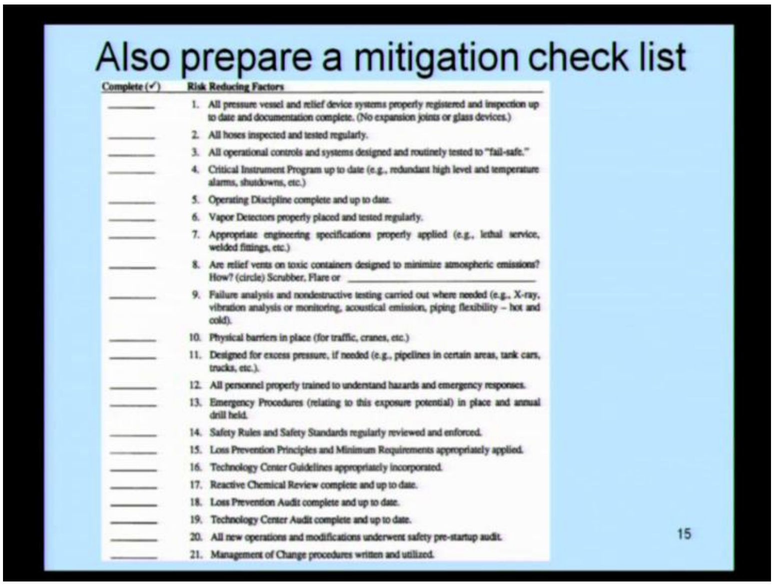
What is the name of the plant which you are analyzing, kindly enter it here. Where the plant is located the geometric and geographic locations enter it here. What is the chemical you are analyzing for it is riskanalysis please enter the name of the chemical here. If you have more than one chemical possibly present where you want to analyze the chemical risk analysis prepare an exposure summary sheet for each chemical separately.Try to find what the total quantity of that chemical present in the plant enter it here - that is an inventory basically. Locate the largest single containment holding this chemical in the process flow sheet, whether the name is given or the location is given or the capacity is given any form you can enter it here.What is the pressure of the containment under which under which it is operating and what is the operational temperature of the container in degree Celsius. These values are got to be given.

So, all these are basically prior information available to you, before you start the CEI.Now you pick up the scenario being evaluated, is the scenario a gaseous release or a liquid release. For that release try to determine the airborne release rate which isAQ given in kilogram per second or pounds per minute. I will advise you to strongly follow SI unit therefore, fill up the value in kilogram per second; also obviously, I have not given you any equations for non SI units at all in my presentation.

Once you get the AQ value for a specific type of scenario maybe gas or liquid release, try to compute chemical exposure index from the equations given in the previous presentation.For the chemical exposure index, for the chemical being identified look at the ERPG guideline, and try to find the concentration and the hazard distances. Try to obtain the concentration of thatchemical in mg by cubic meter, and enter those values here; if you have ppm also you can always convert them in the vice versa form using standard equations explainedin the previous slides.

Once you get the hazard distance in meters or in feet as per the requirement of the client then distances to which the public generally considered as a door property land enter the details or meters; also enter the non company plant for business in meters, and also enter other company facilities in meters. Because you know what the safe hazard distance beyond which you can locate the public, you can locate the company facility, you can locate the non company facility or any other business plant. So, also see that you are preparing this report and list any sites, any odour, any sound you hear here - physical observation and you are about to enter your name;this is got to be reviewed with somebody his name will be there then you have to enter the date at which it has been reviewed and all details. So, this becomes a comprehensive report which I call as chemical exposure summarysheet.

(Refer Slide Time: 25:02)



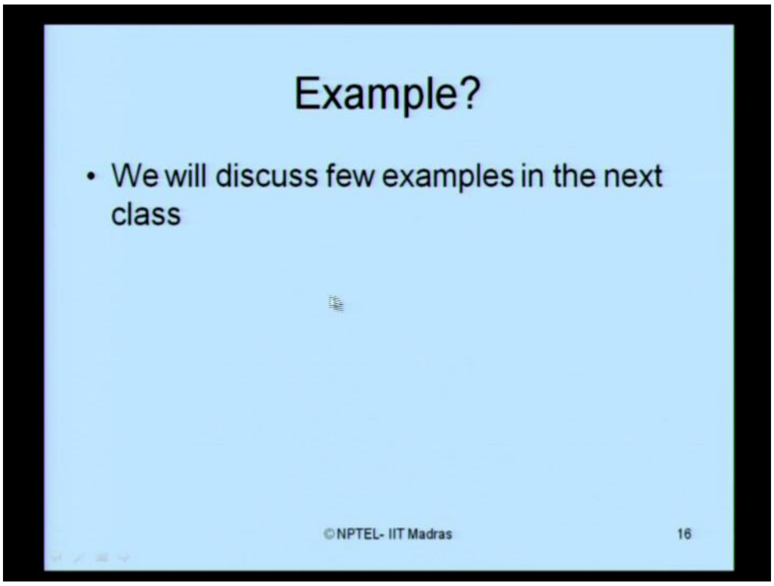
Also prepare what I call is a mitigation check list along with the chemical exposure summary sheet.This is a very simple mitigation check list which is related to what I showed you in the previous lecture for an automobile checking.For example, I had a car, I want to go for a long drive during vacation what kind of check list I will prepare, sothat I can avoid basically the risk involved in the driving. Similar to that I can prepare also a mitigation checklist for chemical exposure index which I can list the risk reducing factors whether all pressure vessel and relief device systems.

Properly registered and inspection has been done; check whether it has been done or not, whether all forces inspected and tested regularly please check that; whether all operational controls and system design and routinelytestedto fail safe; whether the critical instrumentation program up-to-date has been done’ whether operating discipline complete and up-to-date. Whether vapor detectors properly placed and tested regularly; whether appropriate engineering specifications properly applies; whether all the relieve valves and toxic containers designed to minimize atmospheric emission; whether failure analysis and non destructive testing have been carried out; whether physical barriers are in place, whether the design for excess pressure if needed; whether all personal properly trained to understand hazards and emergency responses.

Whether emergency procedures related to these exposed potential is in place and an annual drill being held on this kind of procedures; whether safety rules and safety standards are reviewed and enforced; whether lost prevention and principal and minimum requirements are appropriately applied;whether technology centre guidelines appropriately applied or incorporated; whether reactive chemical review is completed; whether loss prevention audit has been done whether technology centre audit has been competed; whether all new operations and modifications underwent safety prestart up audit; whether the management of change procedures has been written and utilized.

So, prepare a simple checklist of mitigation like this, which will all help to reduce the risk and these are what we call as risk reducing factors. Based on this checklist which is presented along with the chemical exposure index report, one can easily attempt to have a safe operationable features on a plant.

(Refer Slide Time: 27:52)



Now, you will be interested to know what kind of examples we will solve on chemical exposure index. Yes, we will at least solve fewexamples in detail will discuss them in the next class.

Thank you.