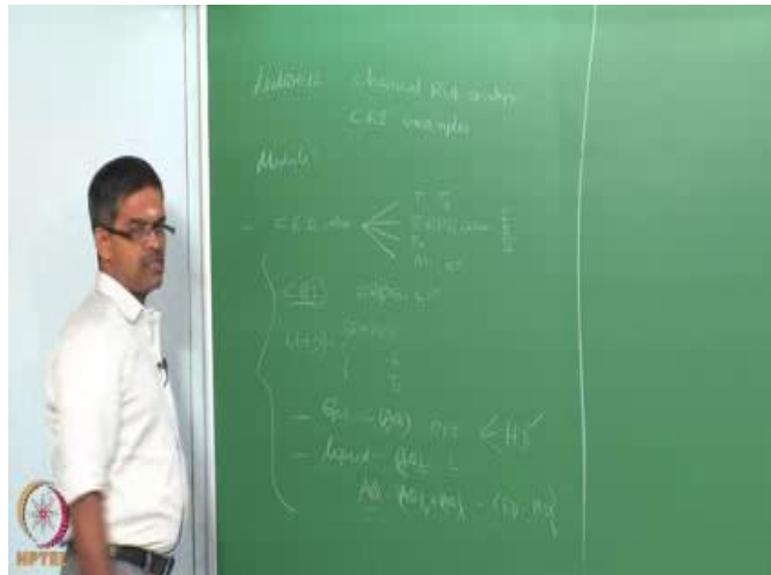


Health, Safety and Environmental Management in Offshore and Petroleum Engineering
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Module - 03
Accident modeling, risk assessment and management
Lecture - 12
CEI – examples

Friends welcome to the 12th lecture in module 3, where we will talk about examples problems on Chemical Risk Analysis.

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We will talk about CEI example in this lecture. This lecture is in module 3, where focus is Accident Modeling Risk Assessment and Management

In the last lecture we discussed about how to get the CEI value, that is a index value. If we really know some elementary parameters of the chemical or the gas being released, for example, operation temperature the boiling point of the chemical of the liquid, then the ERPG is values for various levels 1, 2, and 3 and the operation pressure, the atmospheric pressure and of course, the height of release etcetera.

So, most importantly once you substitute this value for a standards equation as expressed the last lecture which we use now, for the numerical example you will understand a

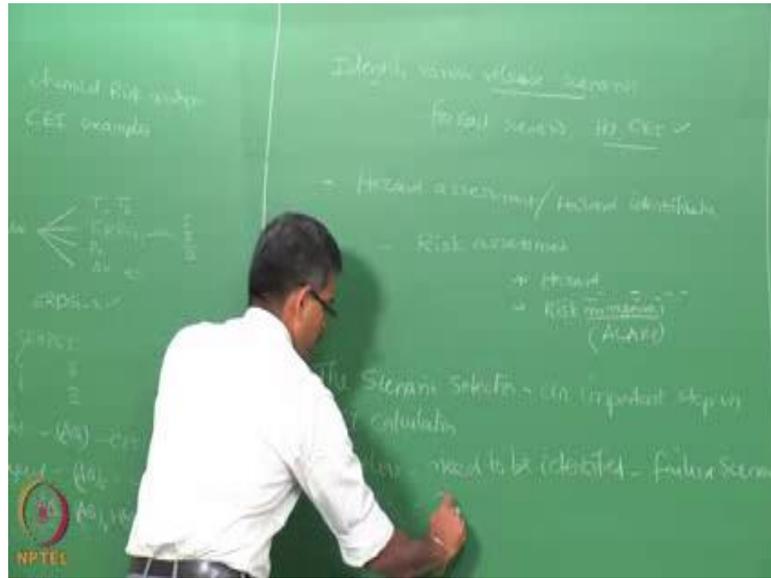
chemical exposure index value for a specific ERPG level, which is essentially ERPG level 2. So, CEI value is always computed for the ERPG concentration level 2, as advised to the international, course; however, hazards distances can be computed for various ERPG levels varying from 1, 2 and 3. So, one can have different hazard distances. So, essential outcome of chemical exposure or chemical risk analysis should be the index which is helpful for me to understand the problem hazard created or expectative created by the chemical release or the toxic release of the chemical.

Second could be what is the maximum distance of influence of risk released chemical on the society on the public. So, again there are 2 ways why is a chemical on the society on the public. So, again there are 2 ways why is a chemical can be released it could be either on the gaseous form or a vapor, it can we also in liquid form the moment it is the gaseous form straight away can fine the air borne quantity using a standard relationship as explained in a last lecture.

Once you know the air borne quantity one can get the CEI value and once you know CEI value for different ERPG level you can get the hazard distance. So, is a straight forward problem as well as gas release concern, whenever a liquid release you need to actually find out what is the air borne quantity of this liquid. So, for that you should know what the flash value is. So, if the flash value exceeds 0.2 of some quantity let us see the air borne quantity should be exactly equal le release late of the liquid then one can also find out the total air borne quantity should be the air borne quantity of the pool plus air borne quantity of the vapor or the flash etcetera if it is less than a specific value once you know the air borne quantity in total then one can find whole the CEI then one can find out the hazard distances for different ERPG level concentrations.

In the whole excise we said yesterday that release scenario, you have to identify the release scenario.

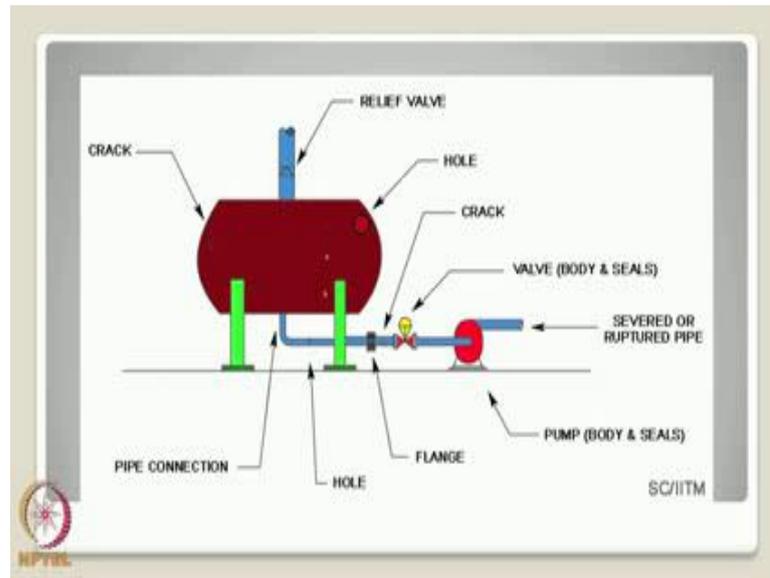
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So, one should identify, various release scenarios and for each scenario, one should compute the hazard distances and chemical exposure index. So, main the problem is for a given plant for a given layout, for a given process layout of a given system, one should be able to identify the different release scenarios what we call essentially an hazard assessment or hazard identification and we all agree and understand that risk assessment essentially starts with hazard identification, then ends in risk management. In between the paths are all of different diversion, where we try to find out the influence of the hazard as chemical hazard of operation etcetera on the whole issue of controlling risk within the acceptability level what we call as Alark that is how it is done.

So, let us take an example now a set of examples as here. So, please pay attention to the figure shown in the screen.

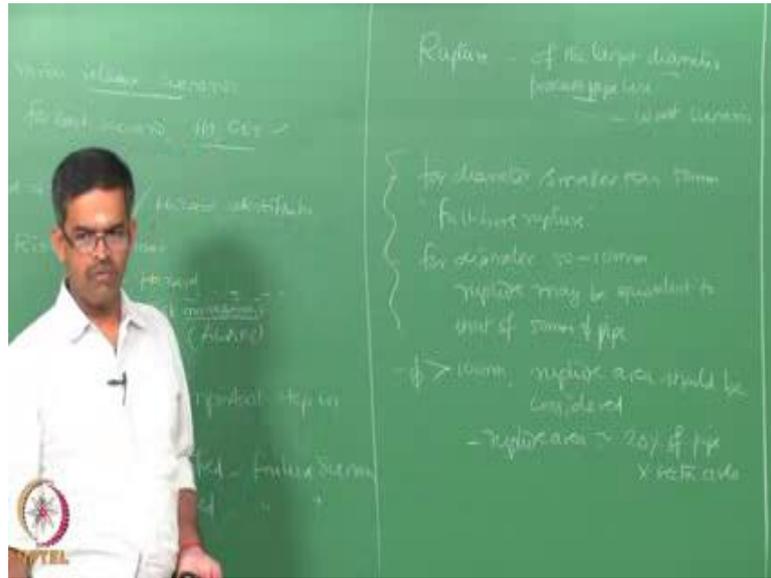
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The figure actually shows basically a vessel or a container which is got a chemical. The container has got a pressure relief wall for emergency releases it is mounted above the ground, and the release from the vessel is taken through a pipeline what we call as the pipeline connection, the pipeline may have a hole or may rupture hole less different that is a connection here the pipeline have also a flange the pipeline flange is connected to the delivery line system, where the valve is fixed and this valve we able to control the flow from the vessel to the delivery system and so on. Now, it is also have a pump the pump has got a specific pipe to be connected further. So, that it is specialized in supply a specific line. So, let us look at this particular scenario and this also has a hole which can be used for excess flow the pipe line can have a crack, the vessel can have a crack, the relief wall may fail let see what are the different release scenarios are hazard scenarios present in this specific case and then see how we can handle this problem.

So, the scenario selection is a important steps in CEI calculation. Now the scenarios of pipeline, what you just know saw is to be identified for different case of failure. So, the pipelines need to be identified for different failure scenarios alternatively, even the vessel can also fail. Once you do this let us straight to look at the failure scenarios in since of rapture.

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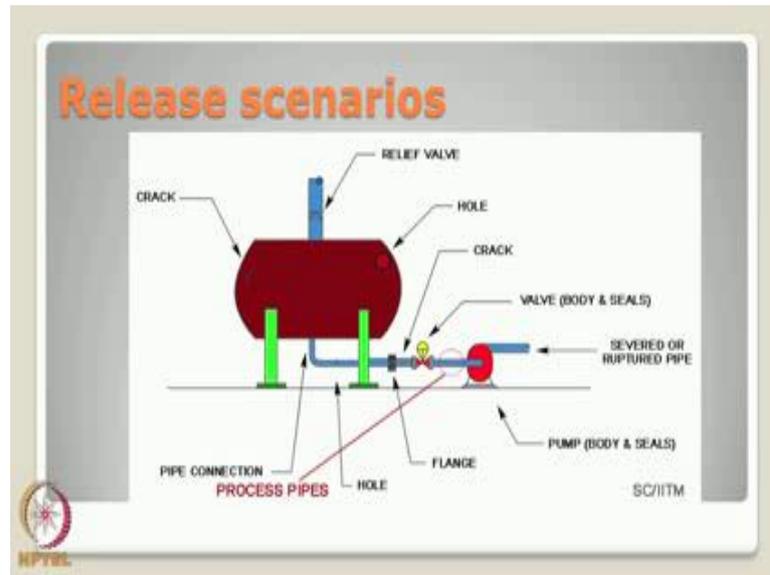
So, rupture could be one cause which can exit out the liquid or the gas in any form. So, rupture is the largest diameter should be the worst scenario. Rupture of the largest diameter, process pipeline could be the worst scenario because pipeline can be of different diameter, let us look at the largest pipeline diameter. So, once we fixed the diameter of the pipeline then there are some interesting regulation given by the international authorities to see how this can be analyzed and initialize as a hazard scenario.

For diameter less than 50 millimeter diameter, smaller than 50 mm, we generally consider full bore rupture, for diameter of the pipeline between 50 to 100 mm rupture maybe equal to that of 50 mm diameter pipe.

Of course, that is the guideline identifies the rupture of the hole from which on the diameter of hole from which this system can be exiting. If you have a diameter greater than a 100 mm then rupture area should be considered. The rupture area should be approximate equal to 20 percent of the pipe prospectation that is the guideline given now let us applied this concept and see what are the possible failure scenarios for the vessel connected to the pipeline which then connected to the process delivery system please be attention to the screen.

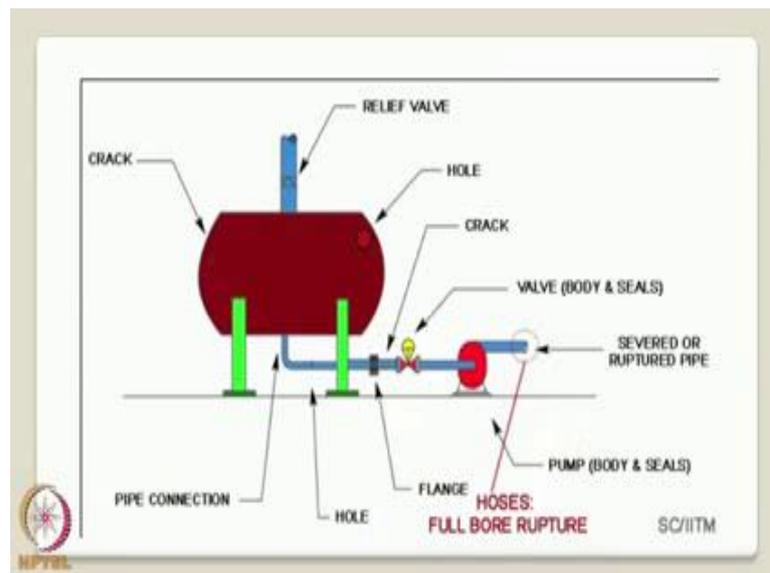
Now, the screen shows various release scenarios.

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Let us say the first release scenario could be the failure in the process pipeline, now there could be a possibility that the process pipeline may fail. If the diameter pipeline is less than fifty millimeter then we take appropriately the value as suggested by the court will take it as full bore rupture. If the pipeline diameter between 50 and 100mm and we should considered equivalent rupture of 50 mm diameter pipeline and so on so forth. So, one possibility is there could be rapture in the process pipeline.

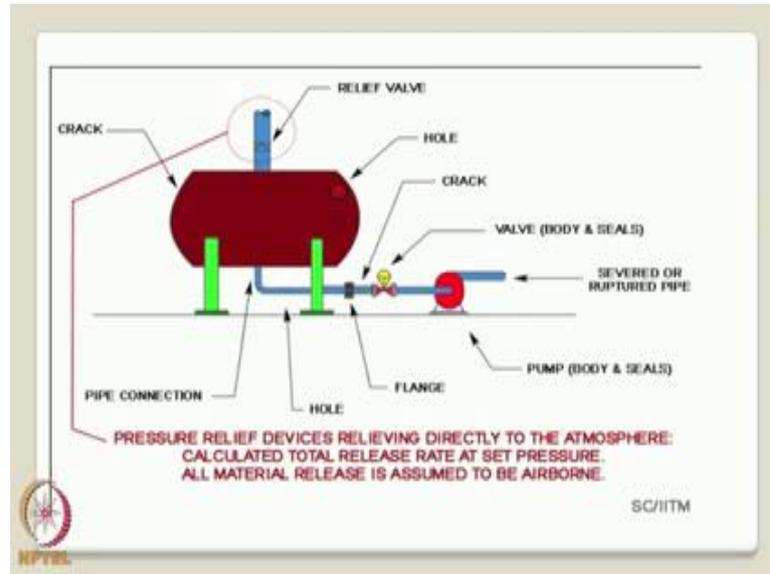
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And other possibility could be the service line may be ruptured the process line the

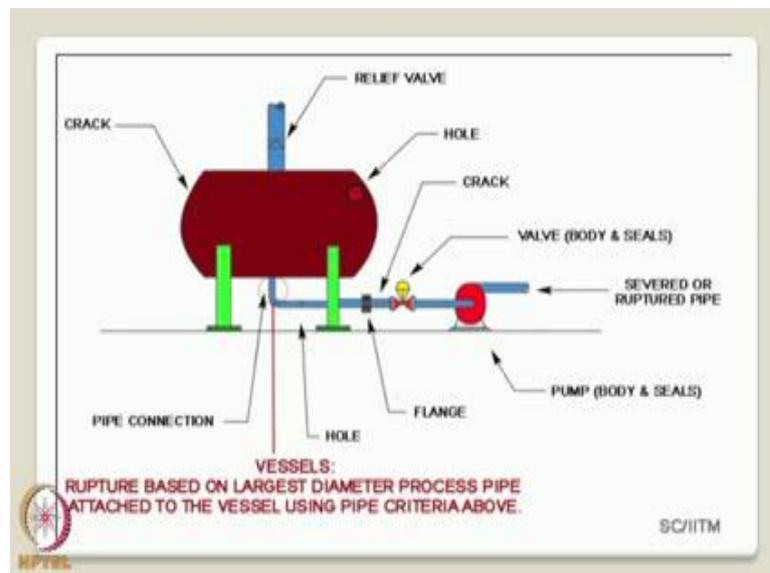
service line this may be rapture it means the hoses which are connected to the pump and the service line can rapture and that can be a full bore rupture.

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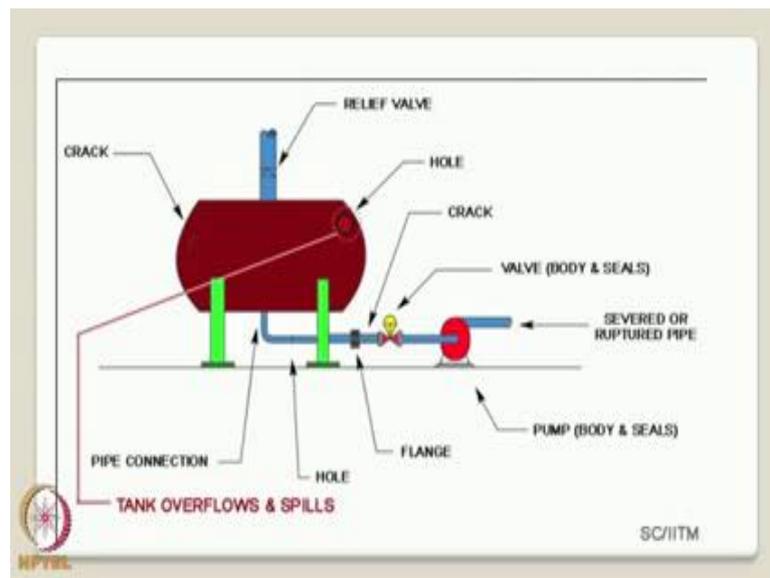
The third possibility could be the pressure relief devices. For example, in this case the pressure relief valve which is relieving the pressure is directly relieving it now to the atmosphere, in such cases the calculated total release rate at set pressure is very important it assumed that all material released is airborne in such kind of failures scenarios.

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The fourth failure scenario could be the connection of the connection of the pipeline from the vessel at the bottom. So, there can be rupture based on the largest diameter of the process pipeline because the process pipeline can have different segments of exit from the vessel in that case considered the pipeline to the largest diameters attach to the vessel using pipe criteria as a discuss just now in this case.

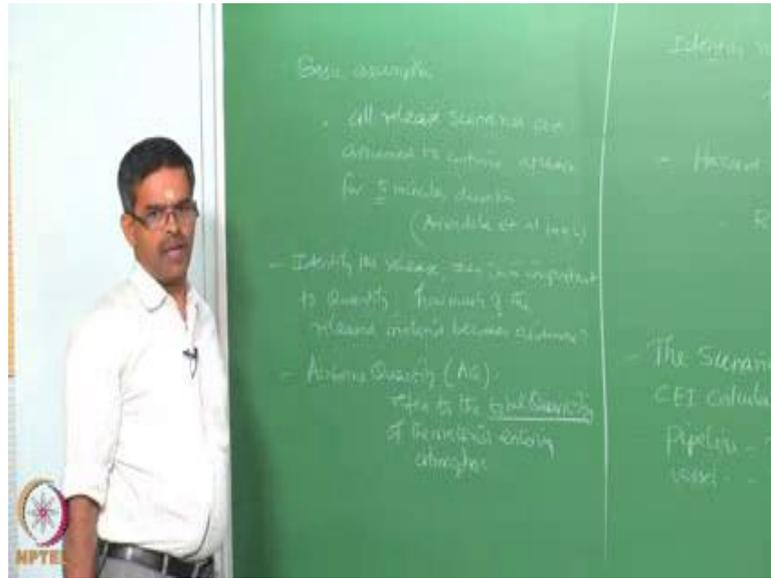
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The next scenario could be there is a overflow hole which is present in the tank and tank overflows from that a through that and starts filling. So, that can be another failure scenario and so on. So, let us quickly see this scenario once again and understand how they have been done.

Let us say one could be the process pipeline rupture, other could be the service line of rupture the third one could be the pressure relief valve is fail. Therefore, the total quantity of material released from the vessel becomes air borne completely; the fourth could be the pipeline connected to the vessel is ruptured. So, then in that case look for the largest diameter the pipeline because that look first cause more worry next could be the overflow hole which is used will also start leaking and tank overflows through this line and starts filling spilling over and so on so forth. It is interesting that there is a basic assumption in the whole analysis.

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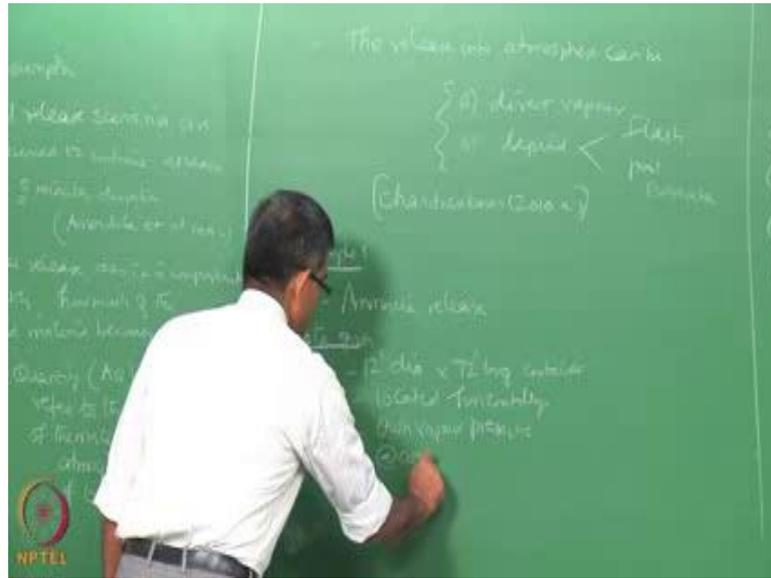


The basic assumption is that all release scenarios as we just no discuss are assumes to continue at least for 5 minutes duration that is an idolization as supported by Amendola et al 1992.

There are some guidelines for estimating the amount material becoming air borne following a release. Once identify the release then it is important to quantify, how much of them is hormone of the release material becomes air borne that is important. So, there are some guidelines the air borne quantity refers to the total quantity of material entry in the atmosphere overtime, air borne quantity which we call as AQ actually refers to the total quantity the total quantity end of the material of the material entering atmosphere over a period of time.

Now, this can be in different form this can be direct vapor release.

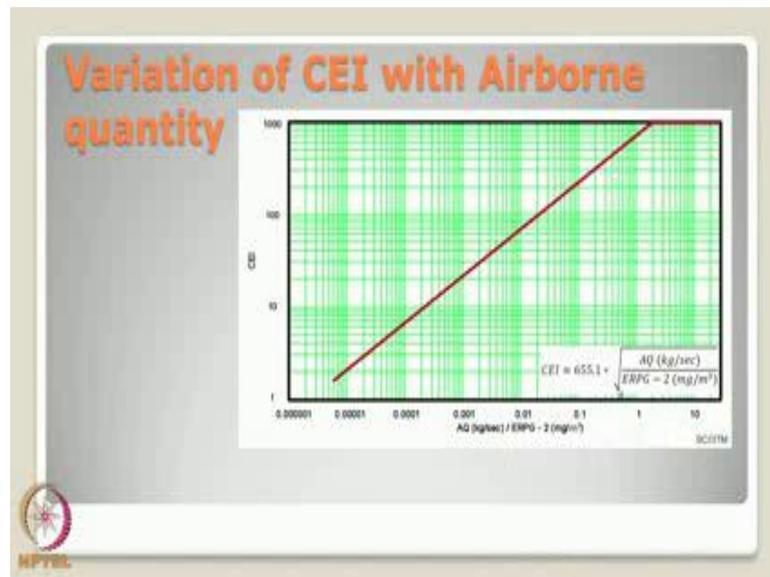
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The release into atmosphere can be A in the form of direct vapor; it can also be a liquid. Once I say liquid then there are 2 possibilities, it can flash off, it can become a pool. So, then that case, pool will also have evaporations. So, one need to work out how much is the quantity which is either getting mixed up in the atmosphere as direct vapor, if the releases in the vapor form if it is liquid, what is the total air borne quantity which is arising from the flash which is the fraction of liquid and which is coming from the pool evaporations which is also part of this. So, you can see that this is supported by Chandrasekaran 2010a.

So, interestingly Ca scenarios considered material to be released both as liquid or vapor. So, variation in CEI with air borne quantity is very interesting and we should see this figure now on the screen.

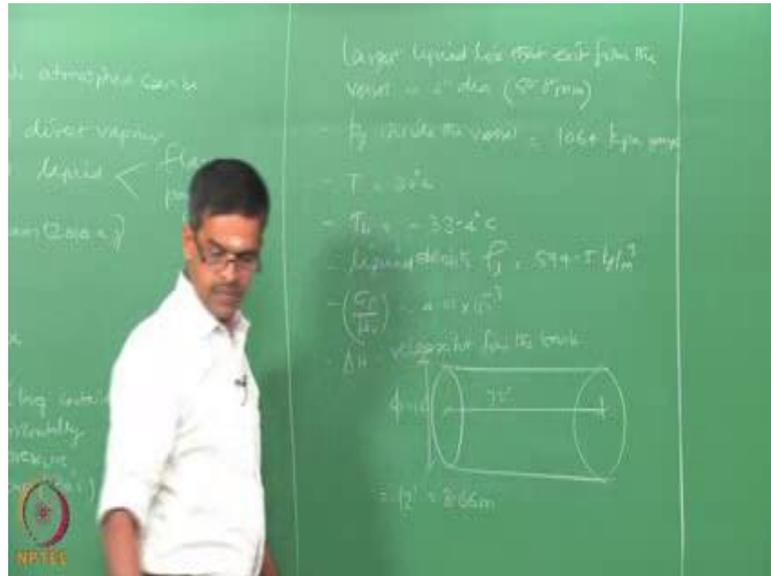
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The screen shows a variation of the CEI value, with air borne quantity one can see here that the air borne quantity in kg per second for ERPG 2 level concentration which is given by this equation is plotted on the x axis, where as the CEI value what you obtain from this equation is plotted on the y axis and we already said the maximum number is 1000. If it is more than 1000 CEI has to be remind is thousand its self we already said that in the last lecture one can see here if various on a log locker if a is linear the CEI value keeps on increasing on a log locker linear for increment in air borne quantity in kg per second, up to a specific value once the air borne quantity comes closer to 1 kg per second in log locker then onwards the CEI actually becomes unchanged, become stoves that is the maximum value CEI can attack. So, that is the variation of CEI with respect to the air borne quantity which is an ideal situation.

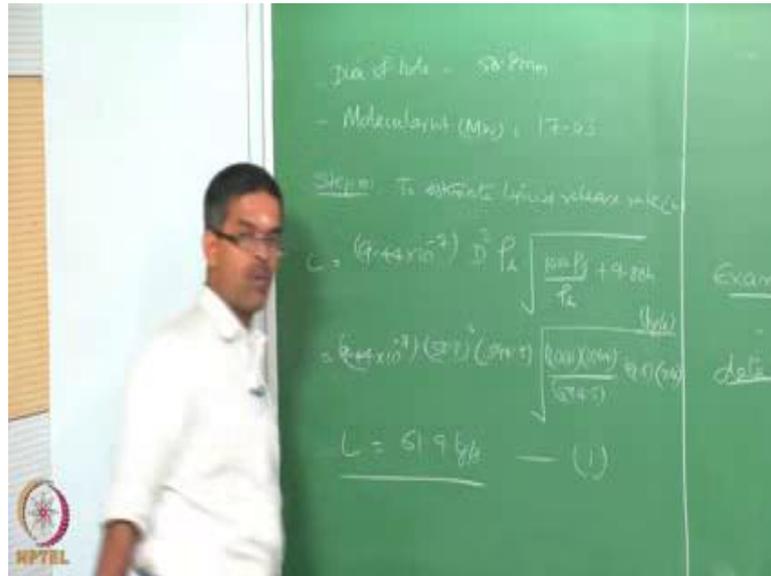
Now, let us take up a problem, let us say example one, let us say the release an ammonia the release is an ammonia release. So, let a say the ammonia is stored in a 12 feet the data given is like this let a say the stored in a 12 feet diameter by 72 feet long container or a vessel, which is kept or located or installed horizontally that is the usual practice how the bullets are installed in process industries it is stored in its own vapor pressure. These are the data given during the hazard analysis it is stored at ambient temperature which is equal to in that location 30 degrees, Celsius. So, we want to identify the release scenario we identified we made an hazard study and let us say the largest liquid line.

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The largest liquid line that exit from the vessel is 2 inches in diameter. So, it is about 50.8 millimeter. The gauge pressure inside the vessel, because it is stored at specific pressure which is 1064 kilo pascal gauge, temperature in inside the vessel is 30 degree Celsius stored in a ambient condition. The boiling point of the ammonia which is taken from the chemical engineering hand book is minus 33.4 degree Celsius liquid density; let us say rho L is 594.5 kg per cubic meter. Cp by Hv the constant is available from ammonia from the hand book which is 4.01 into 10 power minus 3 delta h that is the release height from the tank, we already said the tank is kept horizontal. Therefore, the tank is kept this way and this is off cause 72 feet as given in the problem and the diameter is 12 feet. So, obvious is the height is going to be actually equal to 12 feet the delta h is going to be 12 feet which is about 3.66 meters.

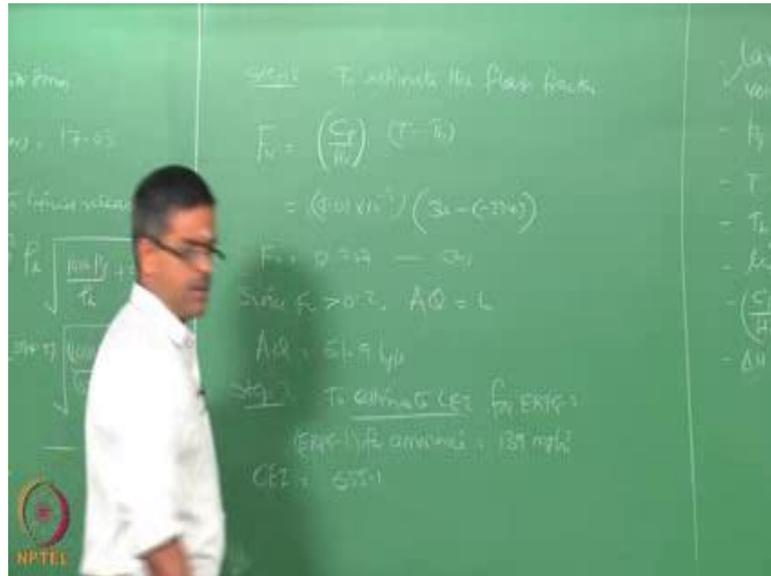
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Diameter of the hole which is 50.8 millimeter because that is the largest diameter of the pipe which is coming out from the exit of the tank, we already said that here molecular weight of ammonia is 17.03. So, step number one I have to estimate the liquid release rate let us say L, L is the given by the equation if a refer back the previous lecture 9.44, 10^{-7} , the constant which is converting all those dimensions with the respect to the units.

So, $d^2 \rho_l \sqrt{10^{-7} P_g + \rho_l g h}$ in kg per second the liquid release rate. So, let us substitute the values 9.44×10^{-7} , d is 50.8 square densities is 594.5 densities is 594.5. So, root of 100 gauge pressure that is 164 kilo pascal liquid density 594.5 multiplied by 9.8 into delta h in this case it is 3.66 meters. So, substitute in do the calculation I will get 1 as 61.9 kg per second that is equation one or value 1.

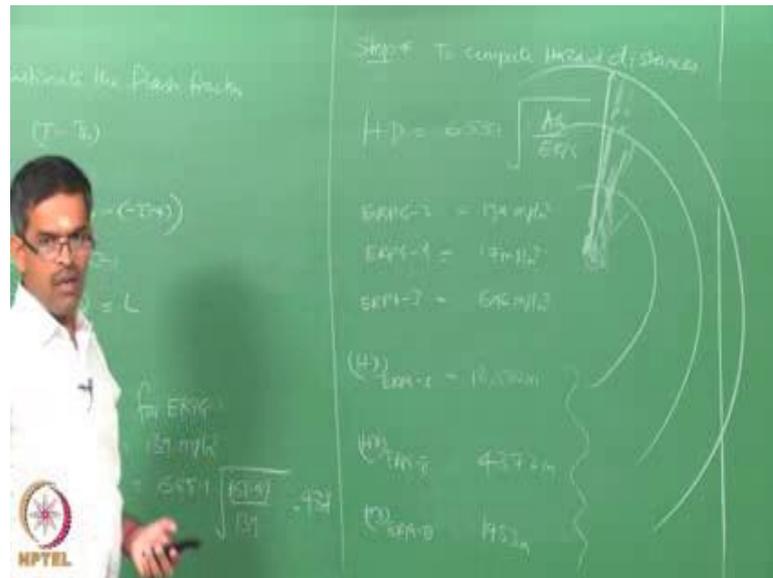
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So, step number 2 being a liquid release I would also like to know, what the estimate of flash fraction is. So, to estimate the flash fraction, I can easily find the flash fraction by the equation given in the last lecture which C_p by H_v of operational temperature minus the boiling quantity temperature which is going to be 0 point C_p , we H_v , we know it is 4.01, 10 power minus 3.

Therefore, 4.01 10 power minus 3 operation temperature is 30 and this is minus 33.4 that is the boiling point and which gives me f_v as 0.2544. Let us say this second value ago, we already known since f_v is greater than 0.2. We should say air borne quantity is exactly equal to the liquid release rate. So, therefore, the air borne quantity in this particular examples becomes 61.9 kg per second once I know the air borne quantity for a given problem I can do step number 3, where I will estimate the chemical exposure index for ERPG 2 concentration. So, the ERPG 2 concentration for ammonia is one 39 milligram per cubic meter. Therefore, CEI is given by a simple equation which is 665.1 root of AQ by ERPG in this case 2. So, which is going to be 655.1 root of 61.9 by 139 which gives me CEI as 437.

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So, step number four I want to compute hazard distances the generally equation of hazard distance is 6551 root of AQ by ERPG. If a really want to find out for ERPG 1, 2, and three separately, one can find hazard distances separately lets write down the values for ERPG 2. So, ERPG 2 ammonia value is 139 milligram per cubic meter ERPG 1, which is taken from chemical engineering hand book this value is seventeen milligram per cubic meter and ERPG 3, is going to be 696 milligram per cubic meter. So, corresponding hazard distances for ERPG one hazard distance per ERPG 2 and hazard distance for ERPG 3, can be computed using this expression as we see above. So, hazard distance for ERPG 2 comes to 4372 meters hazard distance for ERPG 1 comes to 12,500 meters and hazard distance for ERPG three comes to 1953 meters.

Let a see what is the physical interference of this. For example, let us say this was a release point where the vessel is kept release is happening and to this radius hazard distances is calculated the farthest distance is about 12.5 per kilometers. So, any person within this range or any person beyond this stage will have will have a different quality of experience of the release any person beyond this range will not have any effect of the release at all.

Any person between these bands will only have a minor sensitization of the release because there is hazard distance three I mean hazard distance one and this is of course, for 2. So, any person which is closer to this belt in this region will have irreversible

affect, but it not be fatal. So, depending upon the qualitative explanation of ERPG 1, 2 and 3; which explain in the last lecture one can easily physically interpret and understand the seriousness of the influence or consequence of the release on the personnel safety that s the how it is done in case of any (Refer Time: 30:34) release.

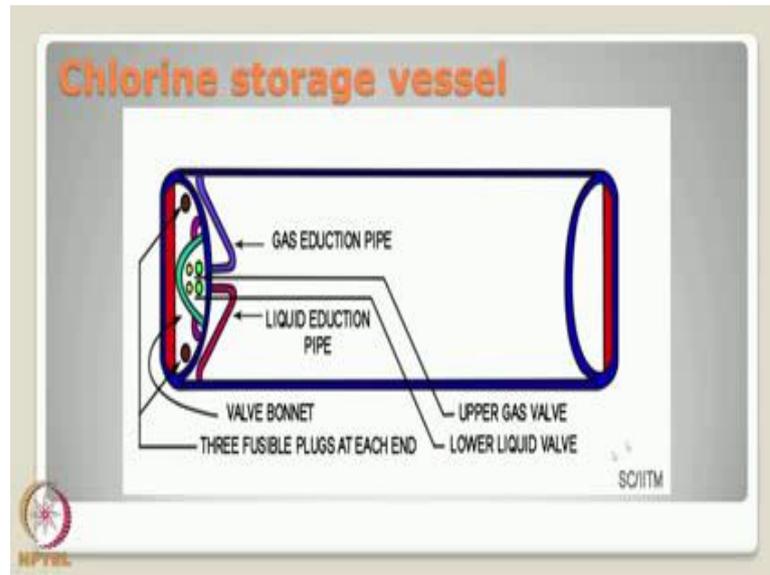
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Let us take an example of chlorine release, let a say a three-fourth inch vapor line is connected vapor connection is happening which is connected to a one ton chlorine cylinder, 1 ton chlorine cylinder stored at ambient temperature is about 30 degree Celsius, let us say this cylinder or cylinder connection is fracture. So, cylinder connection it is fracture.

Please be attention to the screen now, you can see here the chlorine storage vessel which is indicated the figure schematically.

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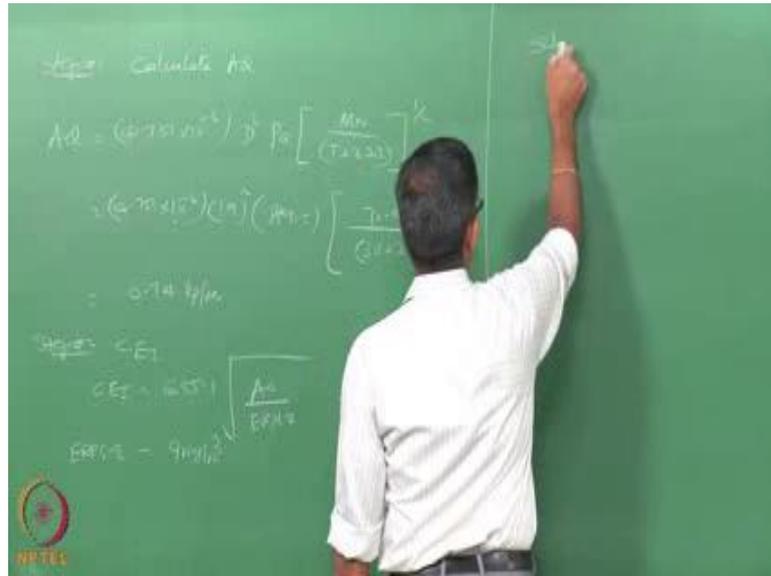


It is got a liquid deduction pipe and a gas deduction pipe and is the valve bonnets which control the release of exit from the cylinder and there are fusible plugs. Which are also used to seal the cylinder? So, that no leakage takes place and there are gas valves that is the upper gas valve shown some by here and the lower liquid valve is the also, there on case because of temperature difference if the liquid starts releasing from the cylinder it can be arrested. So, that is the cylinder and that is the scenario what we going to discuss now.

The gauge pressure inside the cylinder is 788.1 kilo pascal gauge the absolute pressure which is 889.5 kilo pascal in gauge the molecular weight of chlorine is 70.91 the storage temperature is 30 degree Celsius stored in ambient temperature. The diameter of the hole of rupture is three-fourth inch which is 19 millimeter, I want the dimension in millimeters in this case and that is the vessel what you see let us calculate the air borne quantity.

Being a gas is vapor release it will have no pool vaporization etcetera. So, step number one.

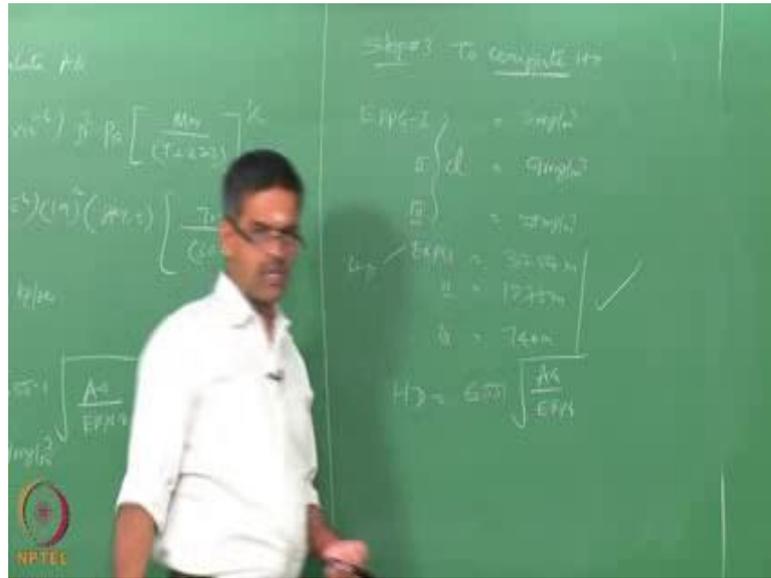
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Straight away calculate the air borne quantity there is no liquid release rate. So, air borne quantity is given by the equation what we saw in the last lecture, $4.751 \cdot 10^{-6}$ diameter of the rupture is 19 millimeters and the pressure is 888.9 and the molecular weight is about 70.91 and the temperature operation is 30 plus 273 and let us say to the power half substituting I get air quantity release as 0.74 kg per second which will remain air borne.

Straight away step number 2, 1 can compute CEI. CEI is given by a simple equation which is $6055.1 \sqrt{Q}$ for chlorine. So, ERPG 2 for chlorine concentration is 9 milligram per cubic. So, therefore, CEI becomes 7088 once a no CEI you can compute the hazard distances.

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So, step number 3 to compute hazard distances I want ERGP, values in level 1, level 2 level 3 or chlorine let us see this values ERPG 2 is 9 milligram per cubic meter ERPG 1 is 3 milligram per cubic meter. An ERPG 3 is 58 milligram per cubic meter. So, hazard distances for ERPG 1, 2 and 3 respectively are for 2 already know for 2 its going to be 1878 because hazard distance can be computed from this equation, which is 6551 root of AQ by ERPG corresponding levels lets substitute for one the value is going to be 3254 meters lets a substitute for ERPG 2 concentration I get 1878 meters. Let a substitute for concentration three which is 58 milligram per cubic meter then I get hazard distances 740 meters one can easily calculate that is how the hazard distance are calculated for this problem.

Friends, in this lecture we understood how to compute the chemical exposure index for different release scenarios, how to then compute subsequently the hazard distances for the CEI values and ERPG level available, we have taken up 2 examples; where we solved 1 for a gashes release and one for a liquid release in the liquid release, we estimated the air borne quantity from the flash fraction and from the pool depending upon the condition for this specific problem. So, chemical engineering hand book is a standard reference which can be useful to estimate at no about all the basic characteristics which are required for working all this problem for a specific chemical or hazardous material to be released in a given scenario.

So, I would urge you to do a sample problem, on your own use a equations and see if you have difficulties please post them the announcement form.

Thank you very much.