Health, Safety and Environment Management in Petroleum and offshore Engineering
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Module No. # 03
Lecture No. # 04
Chemical exposure index (continued)

Ladies and gentlemen, in this lecture we will discuss about more in detail on the chemical exposure index. So, this is lecture on module 3- lecture 4. In the last lecture, we just introduced you chemical exposure index method and we promised you to give one-more couple of examples to be worked out on this particular methodology

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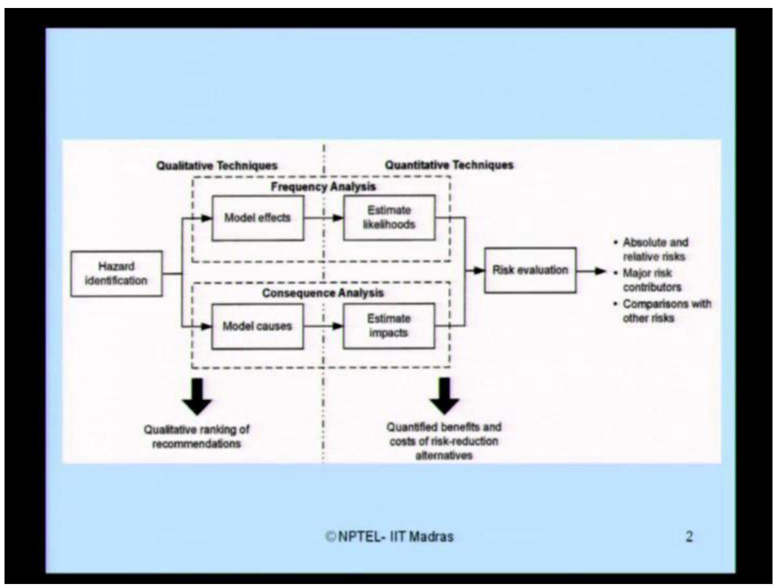

Before you work out an example, let us try to quickly brief where do chemical exposure index analysis method stand in risk assessment modules. If we look at this table, we have got different risk assessment techniques available. Some of them are called as qualitative techniques; few of them are quantitative, so qualitative risk assessment and quantitative risk assessment. If we look at the hazard identification, hazard is scenarios which may get ripen as a risk later.

So, hazard identification has two domains of model effects and model causes. The model effects estimate the likelihoods, so we call this as frequency analysis. The model causes if estimates are on the impact we call its consequent analysis. So, the effect analysis on modules and causes is what we called as qualitative and the estimate likelihoods and estimate impact is what we called as quantitative. Ultimately either you can do a frequency analysis or a consequent analysis to come to risk evaluation from the hazard identification

So, once you do a qualitative technique, you can also get what is called qualitative ranking of your recommendations. If you do the quantitative technique, you can then come up with quantified benefits and costs of risk reduction alternatives. Absolutely once you do a risk evaluation then you try to find out the absolute and relative risks present in the system. The major risk contributors and then compare them with other existing risks and rank them. So, this is an overall scenario of risk assessment.

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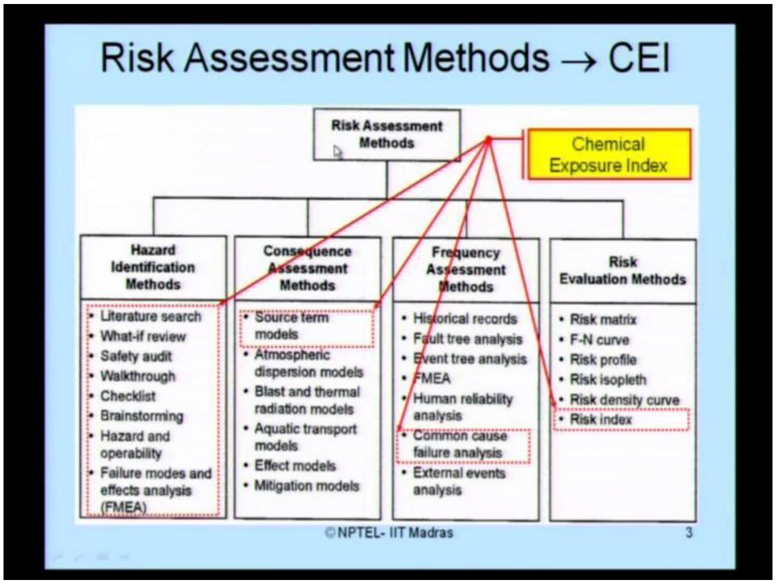

If you look at different methods available on risk assessment, let us check, where do the chemical exposure index method, actually standard. There are different hazard identification methods, for example, literature search; you can do a what-if review; you can do what is called a safety audit; you can also conduct what is called as walkthrough survey. You can prepare your own checklist to see what are hazard scenarios present in a system or in a plant.

You can also conduct brainstorming questionnaire to really identify the hazards present in the system. You can also do what we called as on hazard and operability analysis, which we discuss in detail for many cases. You can also do for design and process FMEA, which we called as failure mode effect analysis.

On the other hand subsequently, if you look at the consequence assess methods, the source term models are to be prepared, then the atmospheric dispersion models can be prepared. Blast and thermal radiation models are available, aquatic transport models are prepared, effect models can be done, mitigation models can be studied. All these aspects of assessment will be what we called as consequence assessment methods.

If we look at the frequency assessment methods then you can look at the historical records of the past event; you can also do what we call as fault tree analysis and event tree analysis; you can also do on FMEA because this will also speak about the frequency assessment. You can also do what we called as on common cause failure analysis and external event analysis.

On the other hand, if you look at the risk evaluation methods, you can do by a risk matrix; you can do by F-N curve; you can plot what we called as risk profile; you can also plot what we called as on risk isopleths; you can also prepare risk density curve and risk index.

Amongst these methods classified as risk assessment methods the source term models, the common cause failure analysis, and the risk index put together in this issue are what we called as chemical exposure index

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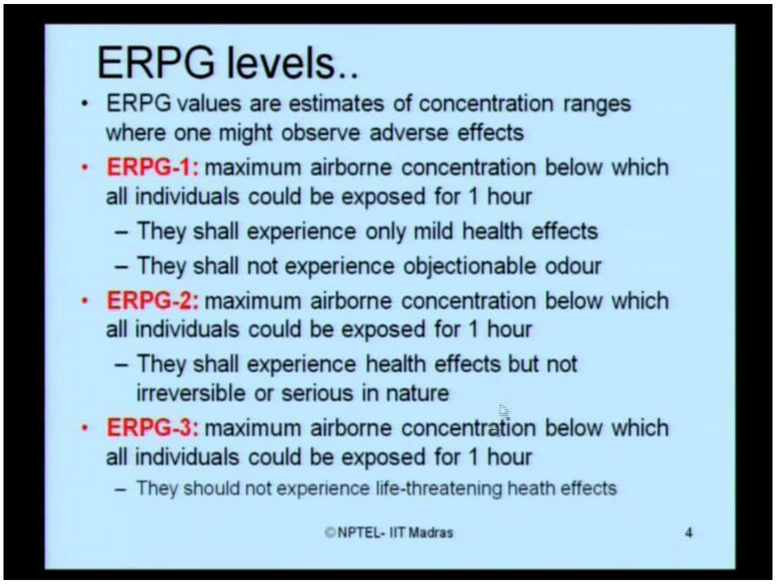

Ladies and gentlemen, you can recollect that in the last lecture we discussed something about emergency response planning guidelines which we called as ERPG. Let us quickly retrieve what do we mean by ERPG? ERPG are nothing but values which estimate the concentration ranges where one might observe adverse effects. The moment you say adverse effect then the question of subjectivity come into play.

I can give a very simple example, you may feel the odour may not be affecting your health very badly or some people may say that the odour is very bad that he cannot stand the smell. So, even a simple issue of a smell can cause adverse effects in certain health condition and not in certain health conditions Therefore, whenever you say concentration range related to adverse effects on human health there is high subjectivity involved. We discussed this issue in the last lecture.

Therefore, international authorities specify ERPG levels in different categories as ERPG-1, which says it is a maximum airborne concentration below which all individuals could be exposed for 1 hour. So, they shall experience only a mild health effects they shall not experience objectionable odour. On the other hand, if you look at the ERPG level-2, it is a maximum airborne concentration below which all individuals could be exposed for 1 hour. They shall experience health effects, but not irreversible or serious in nature.

Subsequently, if you look at the different level of ERPG level-3, it is a maximum airborne concentration below which all individuals can be exposed for a period of 1 hour, but they should not experience life-threatening health effects, but there will be some irreversible or serious effects in nature, but however, they will not be life-threatening health effects cost.

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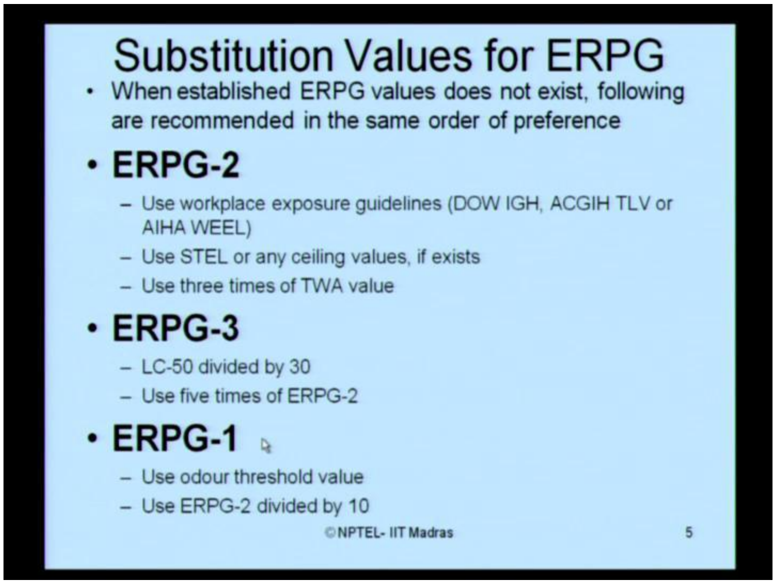

On the other hand, if you do not have any ERPG recommended values for a given process plant then what you do? When established ERPG values does not exist, then you can use the following recommended value in the same order of preference as shown in the presentation now. ERPG-2 value if you want to really obtain, the standard value of ERPG two is not available in the recommended tabular form by the international agency then what you do is use the workplace exposure guideline as given by DOW IGH, ACGIH TLV or AIHA WEEL values. If you do not have them then try to use what we call as short term exposure limit that is called STEL or any other ceiling value which is available for that specific chemical of your plant. If you do not even have the STEL values for the chemical process which you are conducting then try to use time weighted average value and multiply that value by three times and call that as an equivalent to ERPG-2.

If you want to find equivalence of ERPG-3, if it is not readily available in the literature for your specific chemical exposure treatment, then use lethal concentration-50 – the value of

LC-50, and divide that value by 30 and call that value as equivalence of ERPG-3. If you do not have lethal concentration-50 value for a chemical, then whatever value obtained an ERPG-2 multiply that by 5. So that value becomes the value corresponding to equivalent of ERPG-3.

If you want to look at the equivalence of ERPG-1, then use what we call as an odour threshold value. If the odour threshold value for your chemical is not available in the literature then uses the ERPG-2 value calculated as above and divide that value by 10 and use that result as an equivalence of ERPG-1 for your studies

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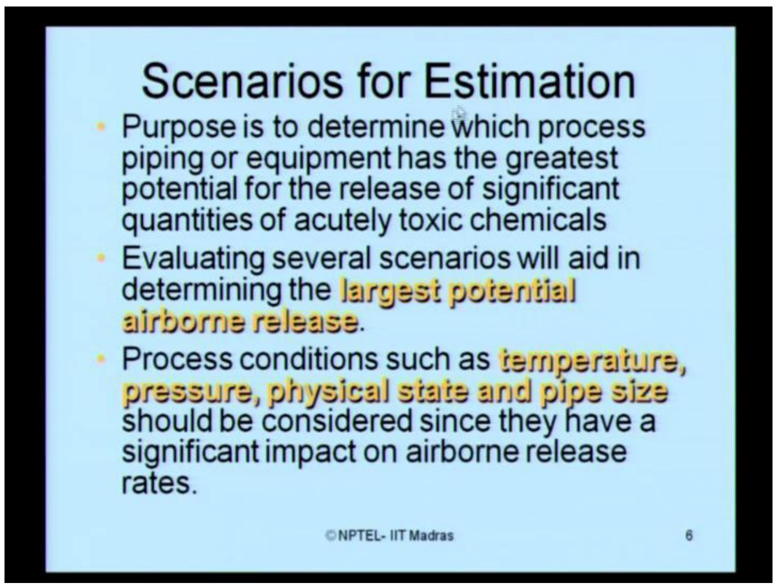

Remember all this ERPG values has got to be updated time to time. Before we start doing an example on chemical exposure index, let us try to ask a question, what do you understand by scenarios for estimating chemical exposure index? What are scenarios where you will look for preparing CEI? The main purpose of identifying a scenario is to determine which process piping or equipment has the greatest potential for the release of significant quantities of acutely toxic chemicals.

What do you understand by this? I have a process or I have set of schemes in the process involved, in that schemes I really wanted to know which is that scenario or the piping segment or the equipment which has the greatest potential for release of toxic chemicals. When I say toxic chemicals, I should always say it is acutely toxic. So, they are not going to cause any fatal effect on human health, but there will be some damage revels to human health depending upon what is the ERPG level of that specific chemical which is being exposed on. So, first for a given process identify or rank the process that has the greatest potential for release of significant toxic chemicals.

Then evaluate several scenarios and that will aid in determining the largest potential airborne release, because you will have many scenarios try to rank them or list them in a priority and identify the scenario that is having the largest potential airborne release. The process condition such as temperature, pressure, physical state and pipe size should be considered in your analysis, because all these factors influence strongly the chemical exposure index estimate, they have a significant impact on the airborne release rates.

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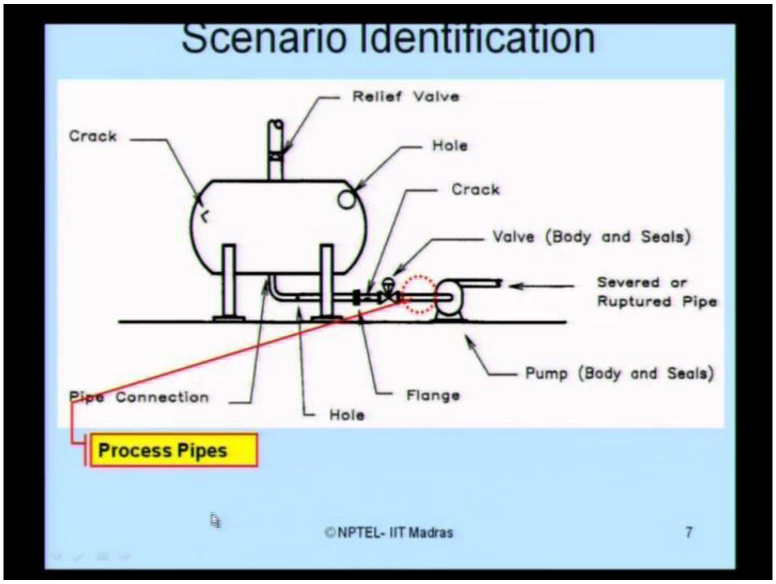

Let us look at the scenario identification example given here. I have a vessel, the vessel has a pressure relief valve, the vessel may develop a crack, the vessel may have a puncture, the vessel is discharging a chemical which is being pumped up for specific segment of a process. So, there can be a rupture in this segment, there can be a crack on the pipeline this is what we called as a process pipeline. There can be a valve which can be mal functional there can be a flange which can be mal functional. The pipe can also develop a hole in due course of time, the pipe connection can have a rupture. So, look at the process which has got many scenarios as I just now discuss.

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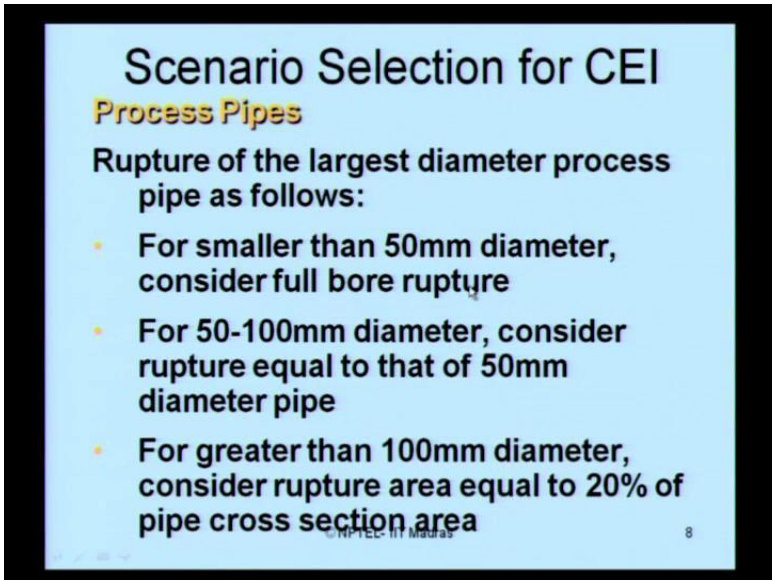

So, in the look at the process pipeline, in the process pipeline you try to identify the rupture of the largest diameter process pipe as follows. For example, your process pipe can have different diameter. For any diameter in the process pipeline, which is smaller than 50 millimeter diameter always consider what we called as a full bore rupture. Because depending upon the rupture diameter, you will actually estimate the airborne quantity of the chemical which is being released. So, if you have any process pipeline, which is whose diameter is less than 50 millimeter consider always what we call as a full bore rupture.

If you have a diameter which varies from 50 to 100 millimeter in size then consider the rupture equal to that of 50 millimeter diameter pipe only. If you have a pipe which is greater than 100 millimeter diameter, consider the rupture area equal to 20 percent of the pipe cross sectional area. That is the general thumb rule which is being followed to actually estimate what could be the rupture diameter or the bore of the rupture diameter in case of process pipelines.

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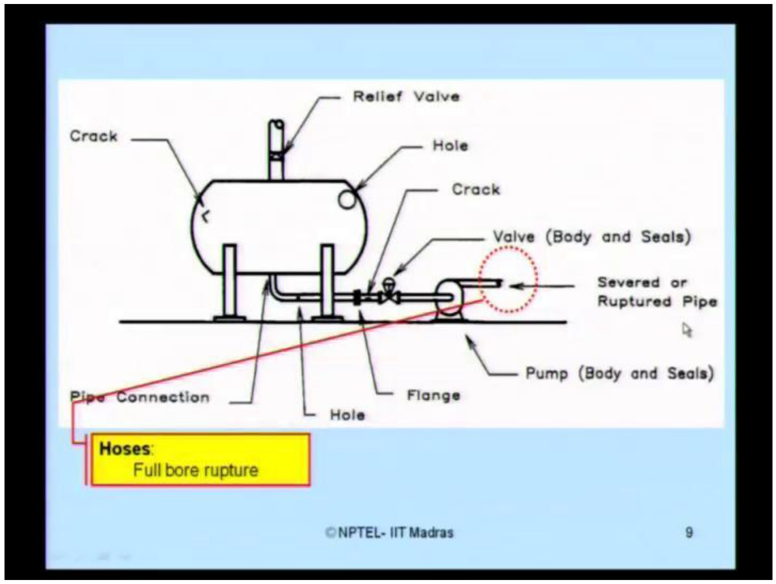

If you look at what we call the exit pipelines where there can be a full bore rupture happening which we called as hose. Because the chemical is being transported or come through a hose to some other container then we can say, if you not really find what will be the scenario related to hose etcetera we will always consider what is called as a full bore rupture.

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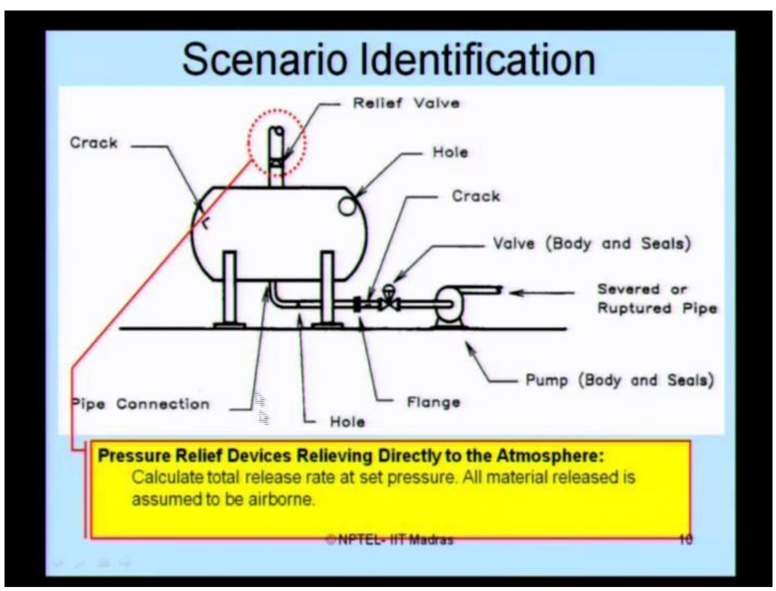

If you are talking about the scenario related to any relief mechanism may be a pressure relief valve. The pressure relief devices which reliefs directly the pressure into atmosphere then calculate the total release rate at the set temperature because the pressure relief valve will have a specific guided temperature at which it is going to work. Calculate the total release at that set pressure. All material released is assumed to be completely airborne. You have got assumed to be quantity of airborne depending upon that an assumption that whatever quantity being released here is completely 100 percent becomes airborne.

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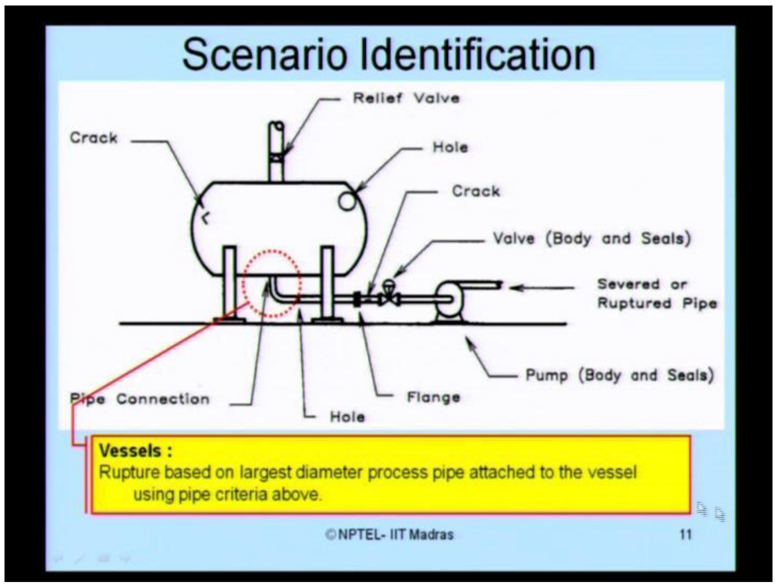

If you look at the connection failure at this junction then the rupture based on the largest diameter in the process pipe attached to the vessel should be considered for the analysis.

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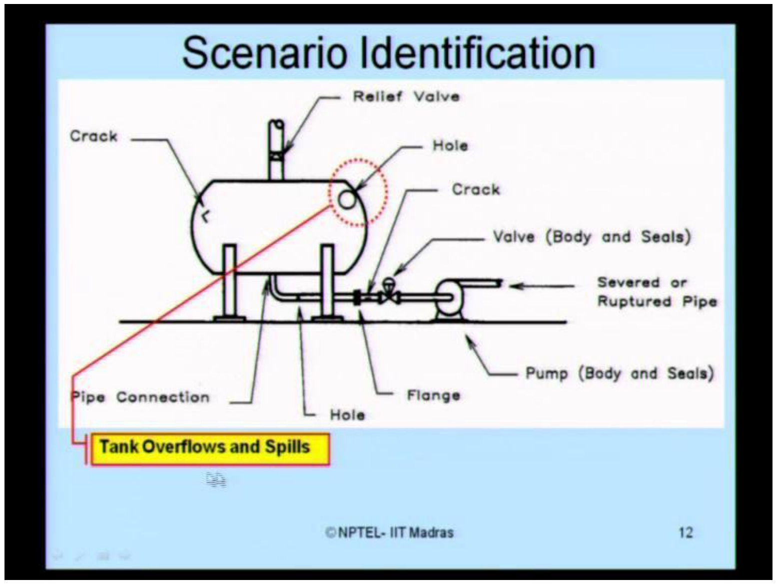

If you look at the scenario related to overflow and spills may be because of the overflow valve on function etcetera then you can also consider a scenario of this kind to identify the hazard analysis.

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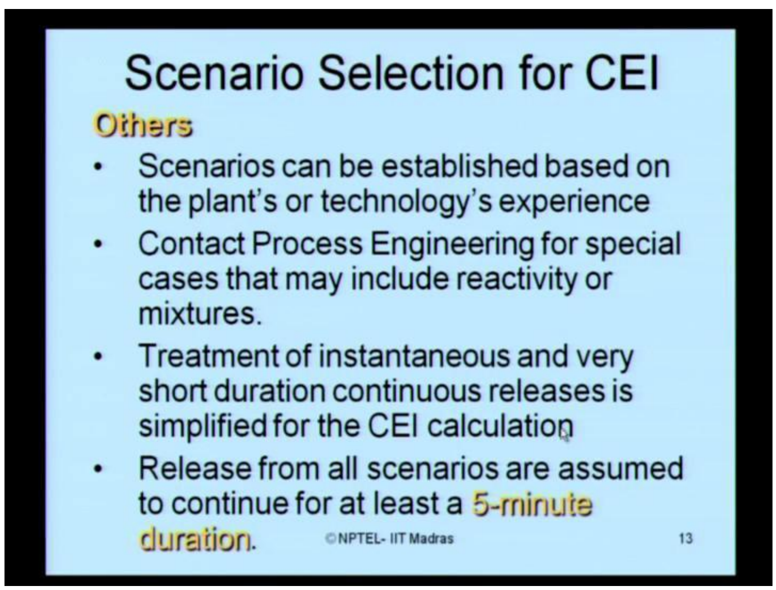

Now, if you look at the scenario selection for chemical exposure index, other than what we discusses there may be scenarios that can be established based on the experience what the person has or based on the process the plant undergoes. If this detail is not available then also one can contact what we called process engineering department for any special case of scenario which can be identified in that specific process, that may include reactivity or some mixtures involved into the process.

You can also consider the treatment of instantaneous and very short duration continuous releases is simplified for chemical exposure index calculation. The continuous release is considered only for a very short duration and that is an assumption what we make, when we use, what we call chemical exposure index calculation. You may ask, what is the subjective value of the short duration? Actually it is considered as 5-minute duration. So, in CEI calculation, we assume that release from all scenarios will take place at least for five minutes.

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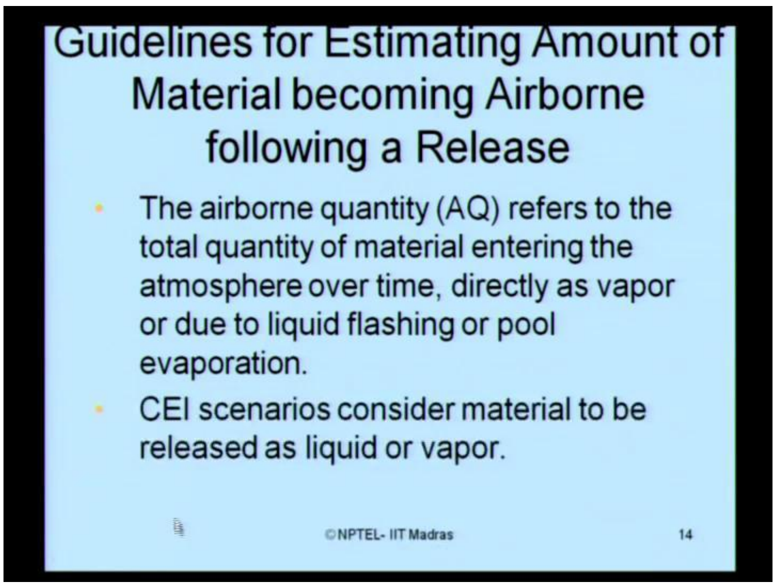

If you look at guide lines for estimating the amount of material airborne coming, following an airborne release, the airborne quantity what we compute for chemical exposure index. Actually refers to the total quantity of material entering the atmosphere over time, directly as vapor or due to liquid flashing or pool evaporation. So, there are three scenarios or there are three possible ways by which the airborne quantity which we refer in CEI calculation can enter the atmosphere over time. One - it can be a vapor; two - it can be a liquid flashing or it can be a pool evaporation. The CEI scenarios consider material to be released as a liquid or vapor.

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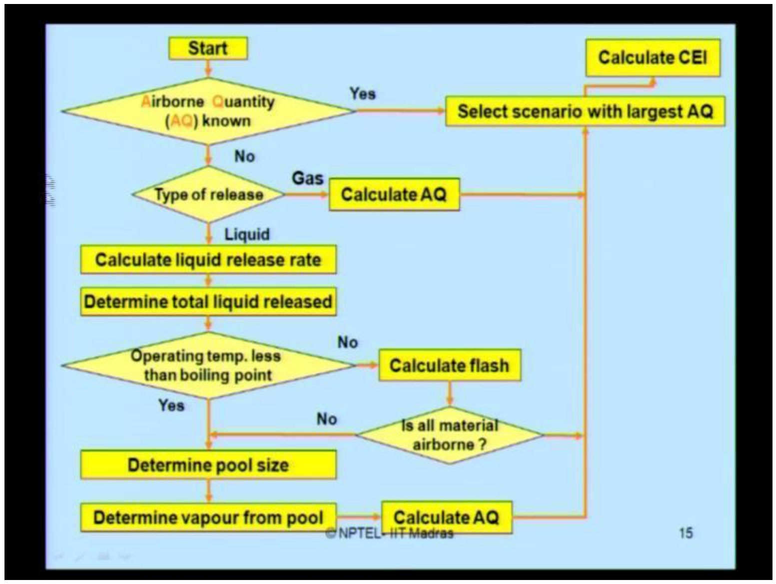

The flow index of how to compute CEI has been discussed in detail, just for briefing we will again review this very quickly. You identify the scenario in a given process there can be many scenarios. You then calculate what we call airborne quantity. If you know the airborne quantity already, select the scenario with the largest airborne quantity and compute chemical exposure index. If you do not know the airborne quantity, first identify the type of release, it may be a liquid; it may be a gas.

If it is a gas, calculate the airborne quantity select the scenario with the largest airborne quantity and try to find out what we call chemical exposure index. For a liquid, calculate what we call liquid release rate then determine the total liquid released for a given operating temperature less than the boiling point. Check whether the temperature under which operation takes place is less than the boiling point. If it is yes, then determine the pool size. If it is no, then it is expected that the chemical being released or the liquid being released will get a flash. Then identify whether all the material is actually airborne or not.

If so, then calculate the scenario with the largest airborne quantity and identify or find out what we call as chemical exposure index. On the other hand, if you estimated the pool size then try to find out the vapor from the pool, and then subsequently calculate the AQ and identify CEI. This is a very comprehensive chart, which discuss how to compute CEI for a gaseous release or for a liquid release. Even in the case of liquid release, you can also calculate the part of fraction as flash and part of the fraction as pool formation.

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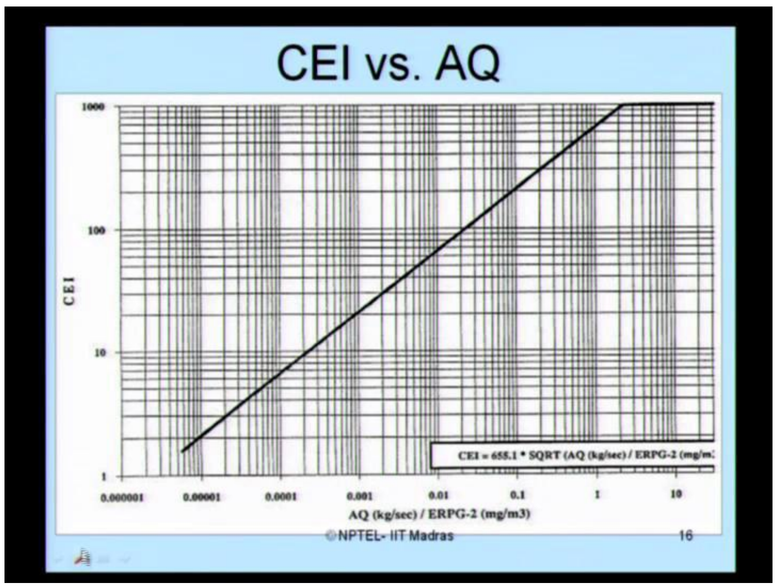

This curve clearly tells us the chemical exposure index versus airborne quantity for different ERPG values. So, if we look at the variation of airborne quantity in kilogram per second for ERPG-2 expressed in milligram per cubic meter. For a different values of AQ varying from zero point five zero(s) of 1 to 10, then obviously, the chemical exposure index number keeps on linearly increasing in this curve.

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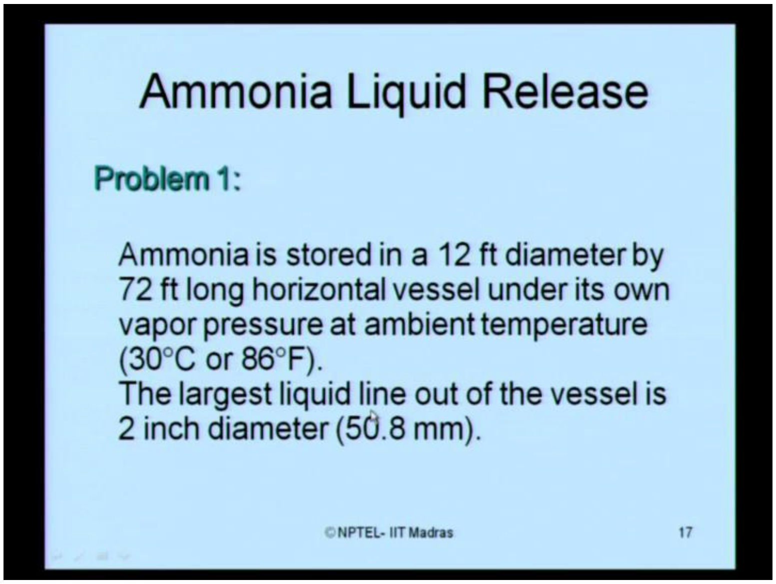

Let us look at an example on ammonia liquid release. What data is actually required for you to calculate the chemical exposure index? First of all let us define the problem. Let us say ammonia is stored in a 12 feet diameter, 72 feet long horizontal vessel. The storage is happening at its own vapor pressure at an ambient temperature probably thirty degree Celsius. You have a storage vessel which is 12 feet in diameter, 72 feet in length is on horizontal vessel. Ammonia is actually stored in this vessel at an vapor pressure at an ambient temperature of 30 degree Celsius. Now, the largest liquid line which is exit out of the vessel is about 50.8 millimeter.

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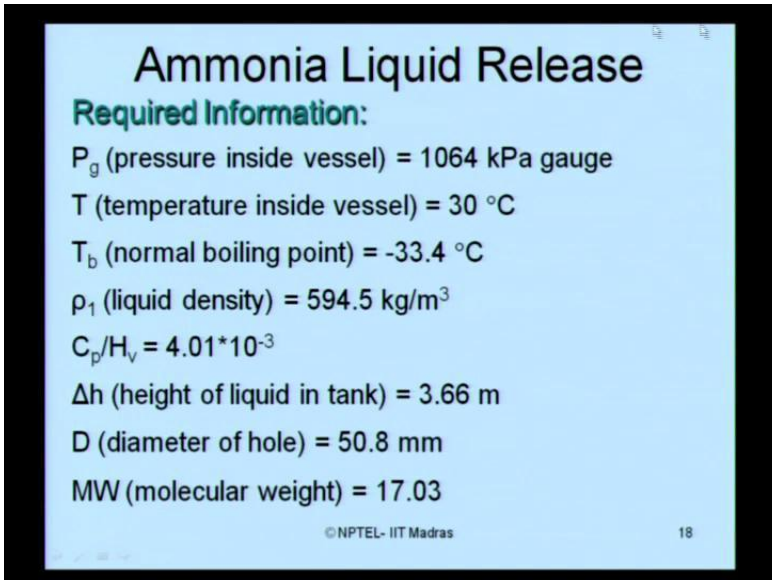

If that is a case, what required information you need to do chemical exposure index. First of all I must know, what is my pressure inside the vessel. It has been given as 1064 kilo Pascal gauge. What is the temperature at which the liquid is being stored? As we just now saw let us consider as 30 degree Celsius - ambient temperature. What is the boiling point of the ammonia liquid which is being and considered. The boiling point available in standard chemical table for ammonia liquid is about minus 33.4 degree Celsius. What is the liquid density of ammonia is 594.5 kilogram per cubic meter. These values are available in the standard literature.

We calculate or we can also get this value directly from the table which we call as C p by H v index which is given for this specific chemical as 4.01 10 power minus 3. What is the height of liquid being stored in the tank? This is the given data; the height of the liquid being stored in the tank is about 3.66 meters. What is the diameter of the hole at which the rupture will occur? The rupture will occur at about 50.8 millimeter. We already said if you have got many process lines for scenario identification. Select that line which is having the maximum possible hazard and if it is the diameter is closer to 50 consider what we call as a full bore rupture. So, I consider here the diameter that has full 50 millimeter being ruptured. The molecular weight of this liquid is being considered is 17.03.

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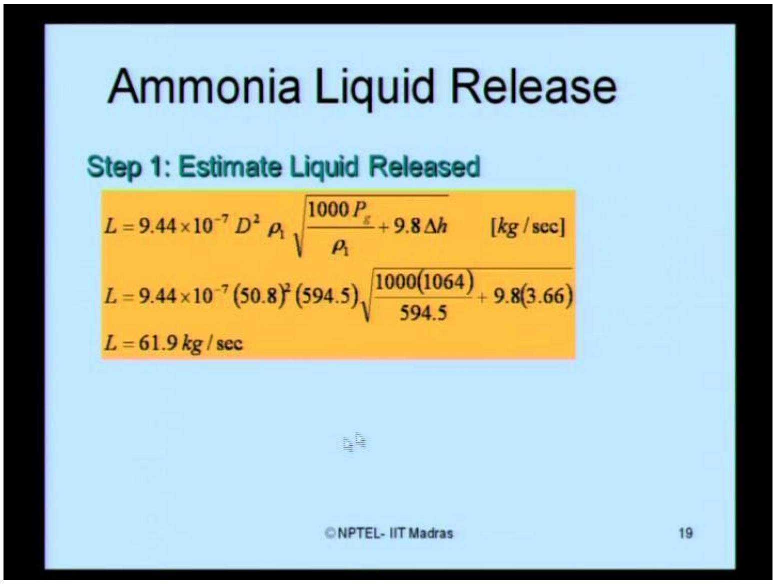

And these data's are readily available to be from the standard chemical table or is available in other form in the literature. In step number one, I try to estimate the liquid being released from the vessel at rupture. So, the liquid being released is given by a simple expression which we discussed in the last presentation. I substitute the values of D rho P g and delta h which we discussed in the last slide, so D – 50.8; rho 1 – 594.5; P g – 1064; delta h – 3.66. So, I will get the liquid being released from the ruptured vessel is about 61.9 kilogram for one second.

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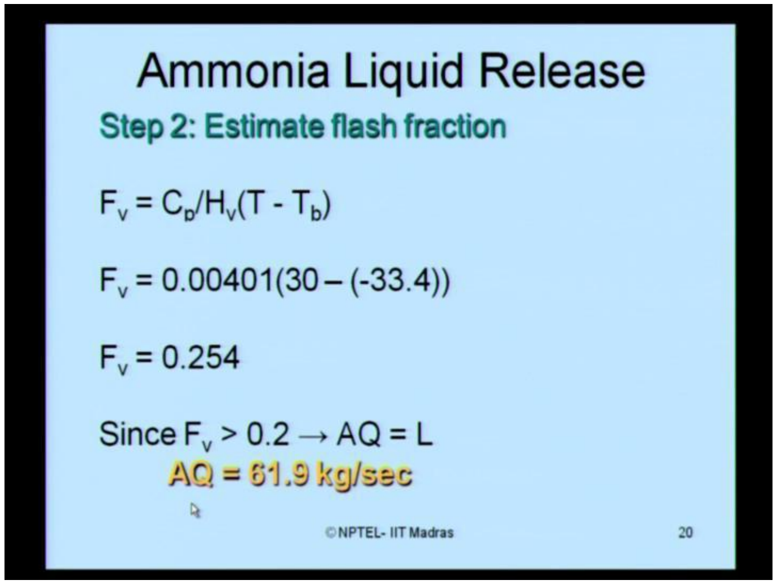

In step number two, I try to estimate what we call as flash fraction. Ladies and gentlemen, you will remember that to obtain whether the liquid being released will become or will form a flash depends upon its boiling temperature. We try to find the flash volume from a simple expression as we discussed here, where T b is the boiling temperature which is being given for the specific problem. T is the operation temperature which is ambient temperature; I consider that as 30 degree Celsius for this problem. C p by H v is a standard quantity available for the ammonia liquid in the chemical tables.

So, I substitute them and try to find out what we call as flash fraction volume which I get as 0.254. And once if this value is greater than 02, I must consider the total airborne quantity as simply the liquid late released which we computed from the step number one. Therefore, my AQ is actually 61.9 kilogram per second which we estimated from the previous step

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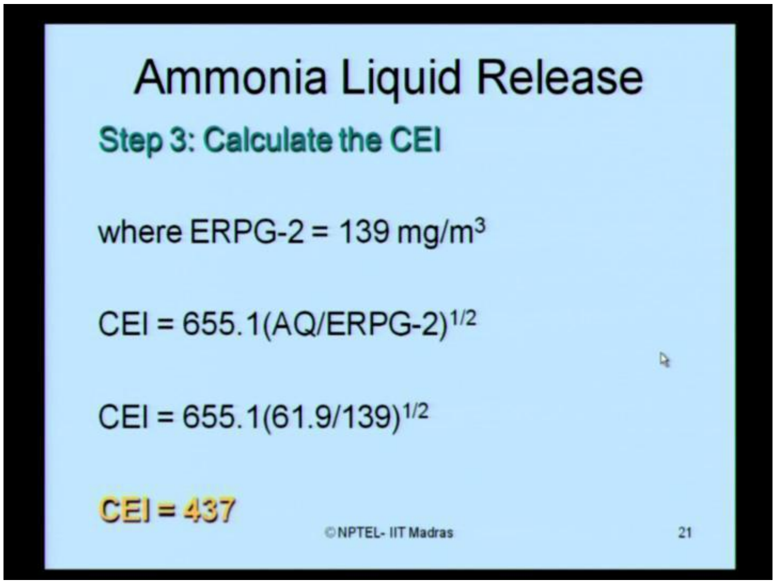

Once I know this then I estimate what we call as chemical exposure index for an ERPG-2. For ammonia liquid international regulatory agencies suggest ERPG-2 is about 139 milligram per cubic meter. Ladies and gentlemen recollect that ERPG will actually give you of safe exposure level for a specific hazard being specified by the international regulatory bodies. There are different levels of ERPG-1, 2 and 3. We discussed them in detail; we can get back to those slides once again to understand what you mean by ERPG-2, so for this specific chemical ERPG-2 is available as 139 milligram per cubic meter.

If you do not have ERPG values for any chemical release which you are computing CEI. Then there are guidelines given in this presentation for you in the beginning to how to find out equivalence of ERPG-2, if it is not available in the standard literature for the process you are looking for. Once I substitute this from a standard equation of this given 655.1 AQ by ERPG-2 square root, I have AQ already estimated from step number two, I have ERPG-2 available for this liquid from this literature and I try to find out CEI value as 437 for this specific release.

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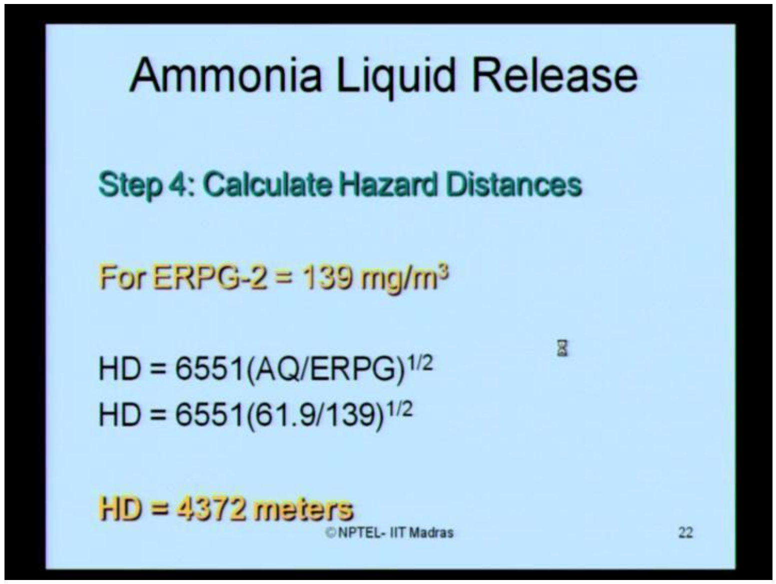

In step number four, I want to compute what are all my safe hazard distances for this problem. Ladies and gentlemen try to understand that in case of any chemical release what we are interested is to not to know how much quantity of chemical is being released. We actually wanted to know how safe the people can be moved or how closer they can be placed, so that they do not generate any health problems at all. So, we are calculating what is called hazard distances. For ERPG-2 of one thirty nine milligram per cubic meter, the hazard distance is estimated from the simple equation given AQ is known to me from step number two ERPG is already known to me. I can consider this ERPG as either 1, 2 or 3.

Accordingly ladies and gentlemen I will get different hazard distances. On the other hand, the hazard distance of x meter will confirm corresponding to any specific ERPG. ERPG is a level of comfort ability of the human health which we discussed in the previous slides. So, for the specific problem after substitution I get for ERPG-2 level hazard distance is about 4.372 kilometers.

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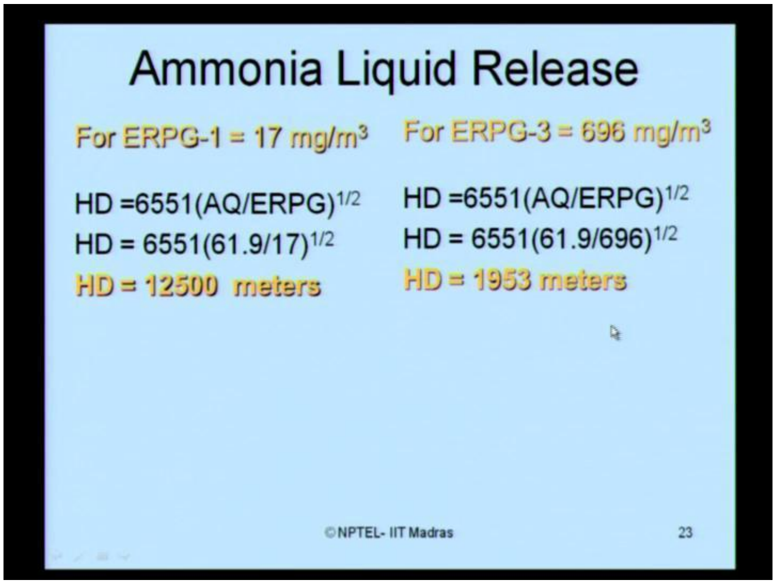

On the other hand, if you also look at ERPG-1 of 17 milligram per cubic meter. Then I can find out hazard distance as 12.5 kilometers. If you also look at ERPG-3 as 696 milligram per cubic meter then you can estimate hazard distance as 1953 meters. Now, you will be able to get an idea hazard distance corresponded to ERPG-3 is 1953. Hazard distance corresponds to ERPG-1 is 12.5 kilometers and hazard distance corresponded to ERPG-2 was calculated in the previous first slide. So, we have three different hazard distances corresponding to three different ERPG states. What do you understand from this? It is a very interesting question; I leave it for your guess.

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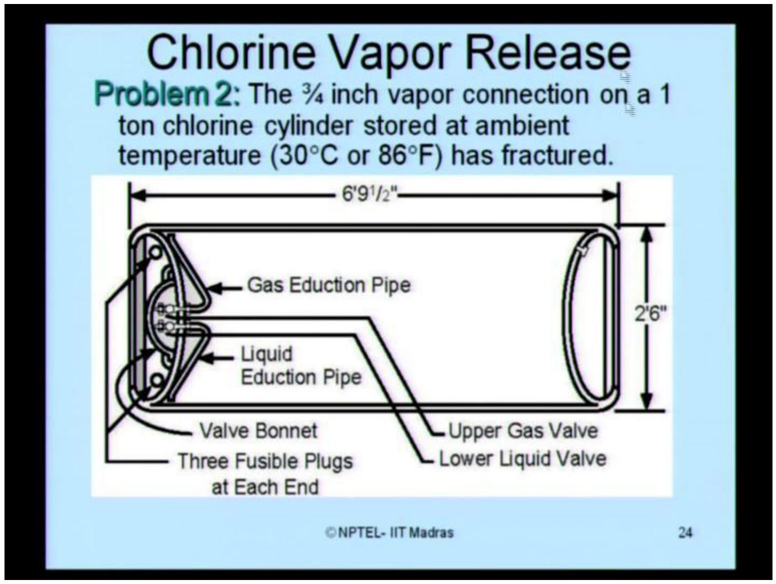

We will look into now second example. A chlorine vapor is being released from a vessel. Consider a vessel of this kind a three-fourth inch vapor connection on a 1 ton chlorine cylinder stored at ambient temperature has fractured. I want to know model this specific chlorine vapor release and try to compute the hazard distance or basically the CEI value for this specific release model. So, there is a tank, the tank dimensions are given to you the process is being explained very briefly. And there is a puncture; there is a fracture through which the chlorine vapor stored inside this has being released. That temperature at which it is being stored is about ambient temperature of 30 degree Celsius and the diameter is about three-fourth an inch of a vapor connection.

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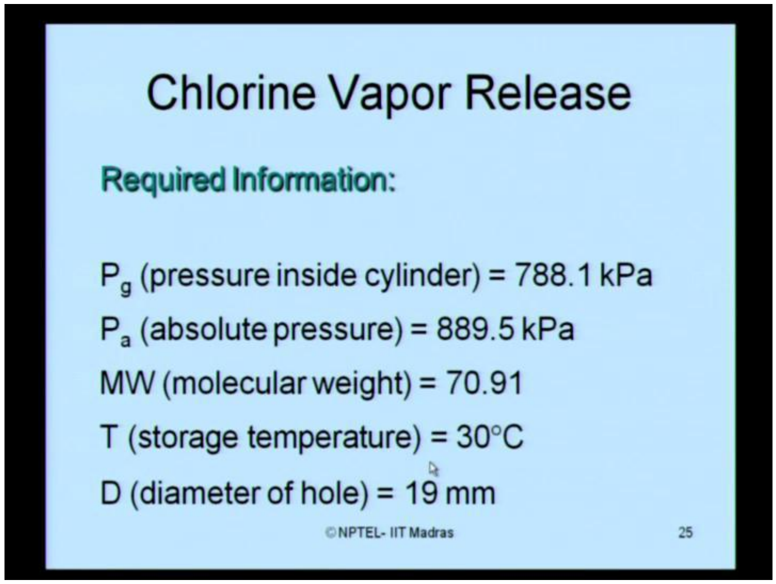

So, what will be the required information for this problem? I would like to know at what pressure this chlorine vapor inside as been stored. So, that is a given data the pressure at which being stored as 788 kilo Pascal. The absolute pressure is about 889.5 kilo Pascal for chlorine vapor. And the molecular weight is 70.91 available from the standard literature; it is being stored in a temperature of 30 degree Celsius. And the diameter of the hole is three-fourth of an inch which is considered as 19 millimeter.

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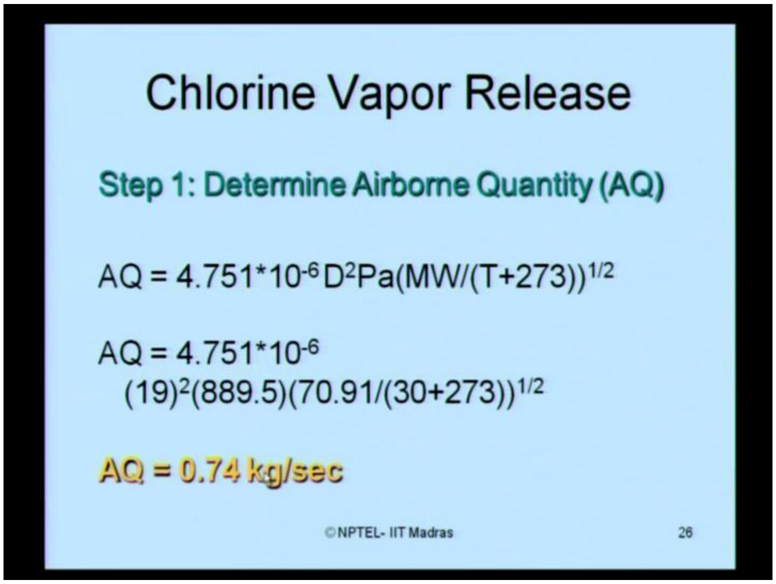

In step number one, I try to estimate the airborne quantity. The airborne quantity is given by for a chemical vapor release is given by this equation. So, I know after substituting for D as nineteen, as P absolute as 889.5 and molecular weight and the ambient temperature of the operation; I compute airborne quantity as 0.74 kilogram per second.

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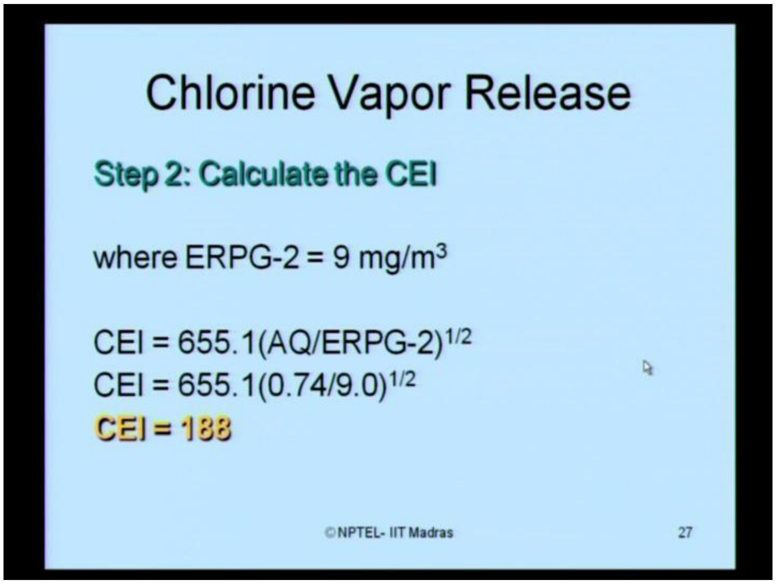

After finding out that is a step number two, I will directly compute as what we call as CEI. For ERPG-2, for chlorine vapor available in the literature is about 9 milligram per cubic meter. The CEI is given by this equation as we saw in the last example as well; I substitute the values and I get CEI as 188. It is a simple number.

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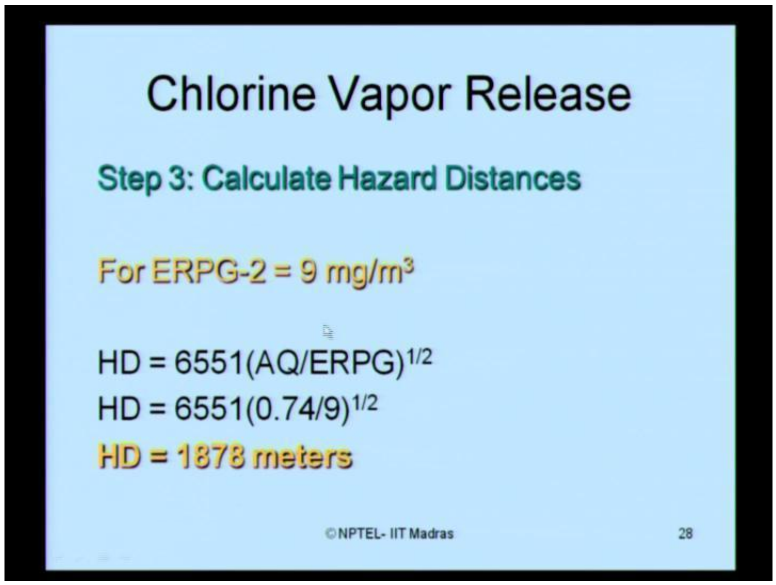

Based on the CEI value obtained for different ERPG levels, I compute what we call as hazard distances. Obviously, as a standard as for ERPG-2 level, the hazard distance given by this equation as explained in the previous example. The hazard distance is known to be 1.878 kilometers.

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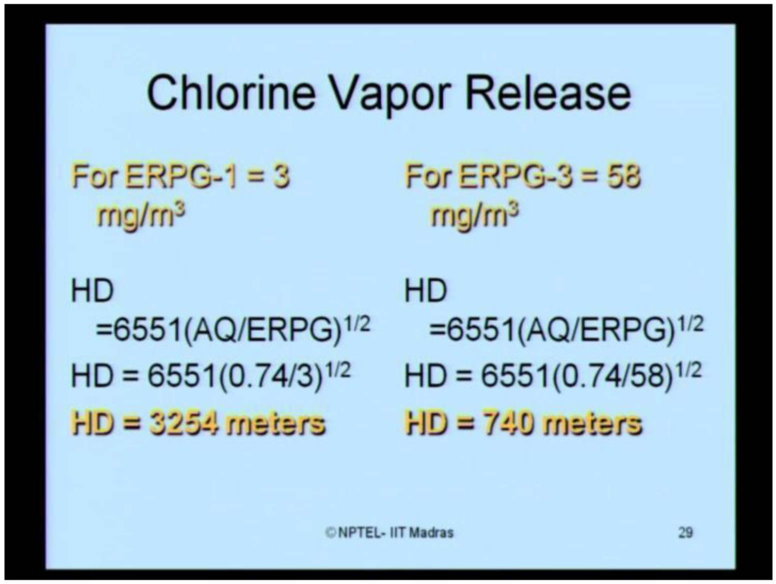

I can also do this exercise for ERPG-1, which is about 3 milligram per cubic meter. And I get hazard distance as 3254 meters. If you do for ERPG-3 level of 58 milligram per cubic meter I get hazard distance as 740 meters. So, we have got two examples solved - one is for a liquid release, other model is for a vapor release.

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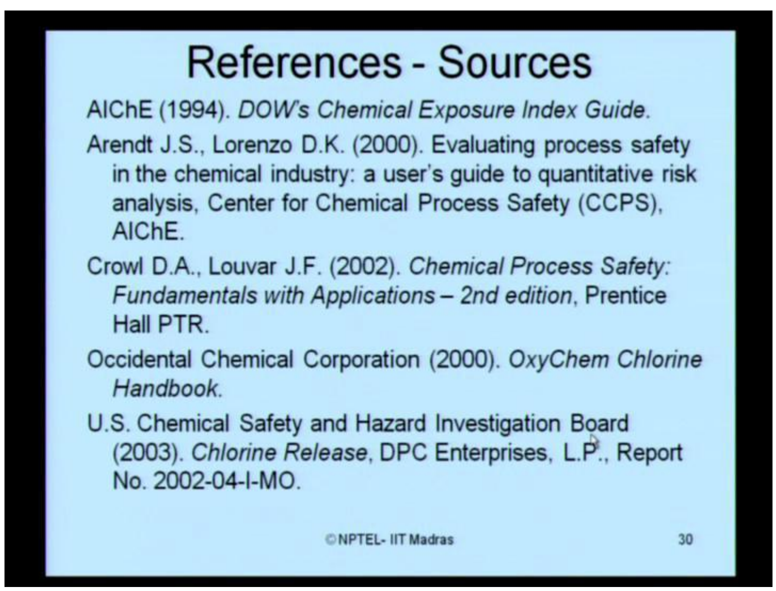

So, these examples and the literature now has been arrived based upon these references which is used further reading. AIChE 1994, Arendt and Lorenzo evaluating process safety in chemical industry and user's guide to qualitative risk analysis center for chemical process safety. Crowl and Louvar chemical process safety fundamentals with application. Occidental chemical corporation 2000, a handbook. U.S. chemical safety and hazard investigation board a report submitted to us.

Thank you very much.