Chemical Process Safety
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Lecture - 16
Problems related to Industrial Hygiene

Welcome to this module, which is related to the different problems of industrial hygiene. So, we had discussed so many concepts of industrial hygiene in different modules, now it is time have look about the different numerical problems, those who are closely associated with this particular a chapter. So, we have in this particular module we have listed 5, 6 problems related to the industrial hygiene, different type of TLVs, etc. So, we are going to take them one by one.

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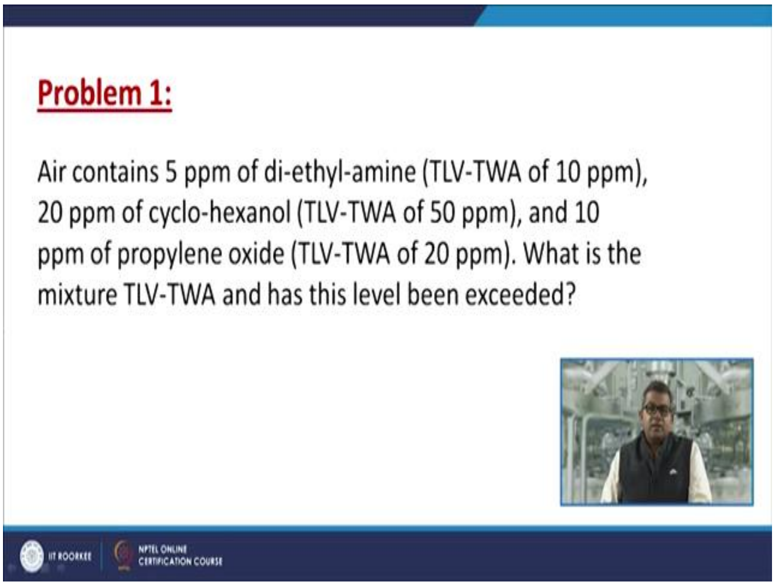

So, let us have a look about the first problem, this problem says that air contains 5 ppm of di-ethyl-amine TLV-TWA of 10 ppm, 20 ppm of cyclo-hexanol which is having the TLV-TWA 50 ppm, and 10 ppm of propylene oxide which is having the TLV- Time Waited Average of 20 ppm. So, you need to calculate the mixture TLV and TWA and you need to also suggest that whether this level has been exceeded for the prescribe one or not.

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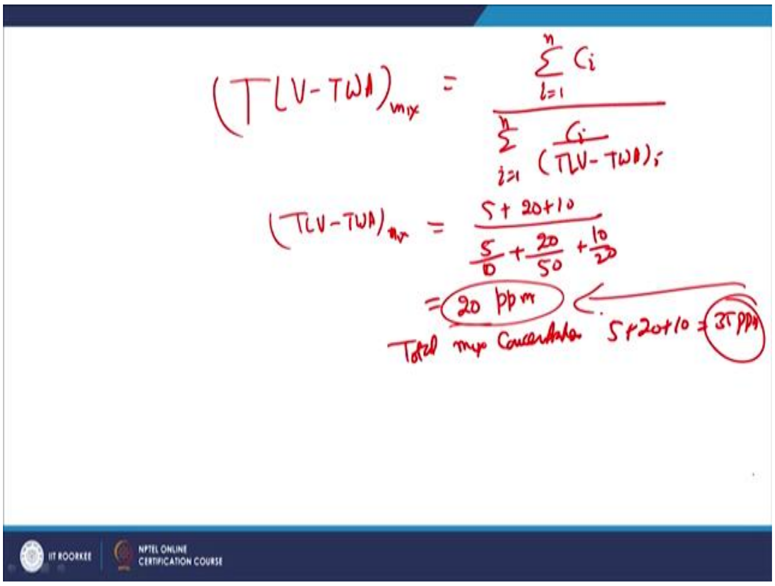

So, let us have a look about this particular problem. So, from the equation which we have discussed in previous model that:

$$(TLV - TWA)_{mix} = \frac{\sum_{i=1}^{n} C_i}{\sum_{i=1}^{n} \frac{C_i}{(TLV - TWA)_i}}$$

Now, if we substitute the values which is given in the problem statement, so the

$$(TLV - TWA)_{mix} = \frac{5 + 20 + 10}{\frac{5}{10} + \frac{20}{50} + \frac{10}{20}} = 25\, ppm.$$

The total mixture concentration is 5 + 20 + 10 = 35 ppm. The workers are overexposed under these circumstances.

So, the now this one is higher compare to this value, so the workers are over exposed in this circumstances, so you need to take certain (approp) certain corrective measures to overcome this particular aspect.

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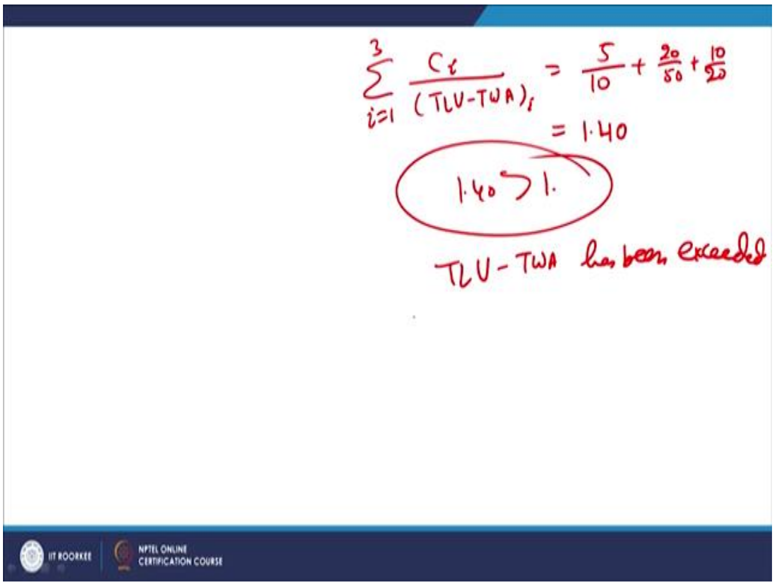

Now, we may adopt another approach to solve this particular problem and this approach suggests that we are having three components.

$$\sum_{i=1}^{n} \frac{C_i}{(TLV - TWA)_i} = \frac{5}{10} + \frac{20}{50} + \frac{10}{20} = 1.40$$

Now, this quantity 1.40 is greater than 1, so once it is greater than 1 then the (TLV-TWA) has been exceeded, so workers are over exposed and you need to adapt the corrective measures to overcome this particular problem.

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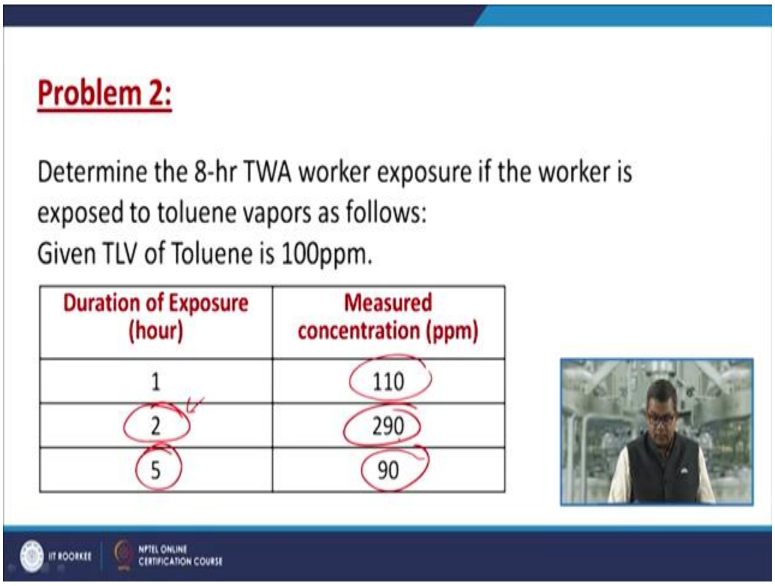

Now, let us have another problem than in this particular problem you need to determine the 8 hour TWA worker exposer, if the worker is exposed to toluene vapors as per the following scheme. Now, the duration of exposer 1 hour, the measured concentration at the work place 110, then again the (worker is over exposed for) worker is exposed for 2 hours with the concentration of 290 ppm and then he in this exposed for 5 hours with measured concentration of 90 ppm.

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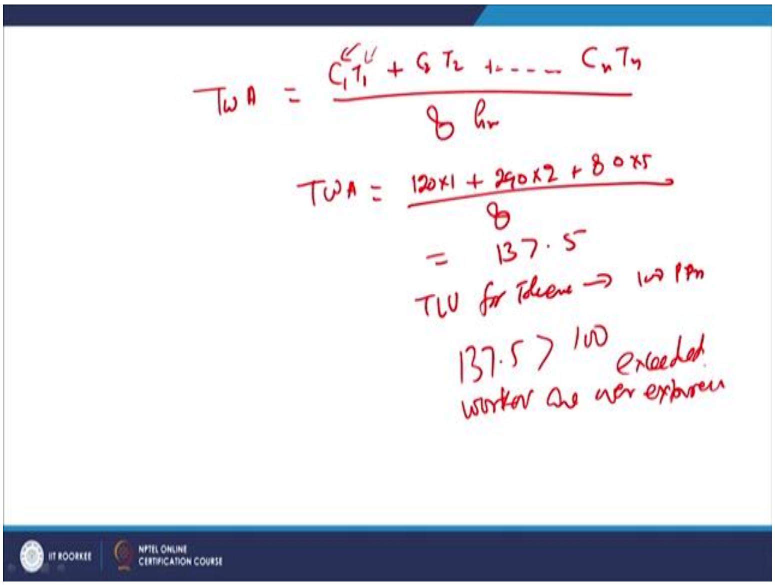

Now, here in this particular aspect, we can use this particular formula:

$$TWA = \frac{C_1T_1 + C_2T_2 + \ldots\ldots\ldots + C_nT_n}{8\ hours}$$

Now, here because we are having two parameters, one is the concentration, and another one is a time. So, this is the concentration and of the component at the work place and this is the time duration. Now, let us substitute the value of the concentration along with the time to this particular formula. So,

$$TWA = \frac{120X1 + 290X2\ + 80X5}{8\ hours} = 137.5$$

Now, TLV for toluene is 100 ppm, now this 137.5 is greater than 100, so it is exceeded and workers are over exposed and you need to take precautionary measures some sort of you can say that temporary respirators or sometimes you may take the corrective measures, so that the (TLV can be) TWA for this particular aspect can be lower down.

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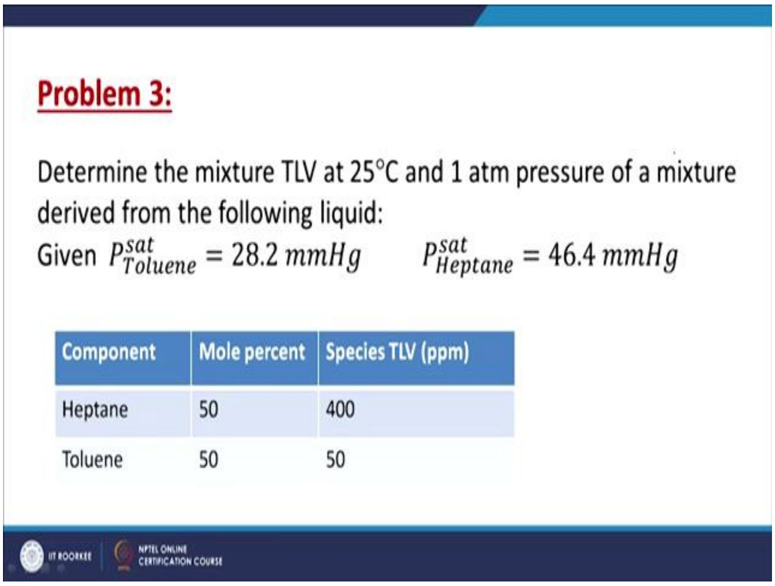

Now, let us have another problem, this is the problem number 3. Now, you here you need to determine the mixture TLV at 25 degree Celsius and 1 atmosphere pressure of a mixture derived from this particular liquid that is given that P saturation of Toluene 28.2 millimeter of mercury and saturation pressure of Heptane is given as 46.4 millimeter of mercury. Now, the mole percent of Heptane is given 50 percent and the Heptane TLV is 400 ppm and Toluene is presented the mole percent of 50 percent and TLV for Toluene is 50 ppm.

Now, here once we have this particular aspect, the solution requires the concentration of Heptane and Toluene in the vapor face. So, assuming that the composition of the liquid does not change as it evaporates the quantity is large, the vapor composition is computed using standard vapor liquid equilibrium calculation.

So, let us assume that the Raoult's and Dalton's law apply to this particular system under the given condition. The vapor composition is determined directly from the saturation vapor pressure of the pure component. So, using Raoult's law, the partial pressures in the vapors we can determine easily with Raoult's law equation.

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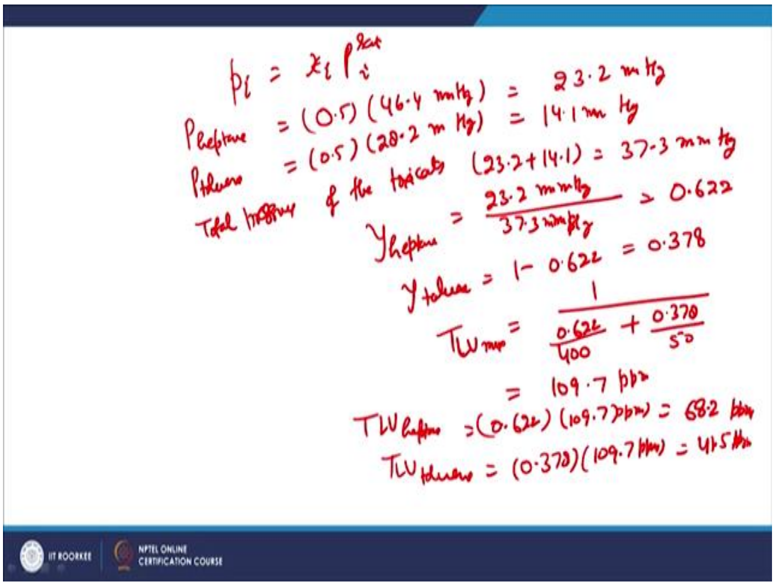

Now, let us have the Raoult's law equation,

$P_i = x_i \cdot P_i^{sat}$

Now, here we are having,

$P_{heptane}$ = 0.5 X (46.4 mm Hg) = 23.2 mm Hg

$P_{toluene}$ = 0.5 X (28.2 mm Hg) = 14.1 mm Hg

So the total pressure of the toxicants = 23.2 + 14.1 = 37.3 mm Hg.

So, if you used the Dalton's law and the mole fraction on toxicant basis i.e.

$Y_{heptane}$ = 23.2 mm Hg / 37.3 mm Hg = 0.622

and for if you calculated for the Toluene,

$Y_{toluene}$ = 1 – 0.622 = 0.378

So, the TLV of the mixture can be calculated by this formula:

$$TLV_{mix} = \frac{1}{\frac{0.622}{400} + \frac{0.378}{50}} = 109.7\ ppm$$

Now, because the vapor will always be the same concentration, so the TLV for the individual species in the mixture are,

$$TLV_{heptane} = \ 0.622\ X\ 109.7 = 68.2\ ppm$$

$$TLV_{toluene} = \ 0.378\ X\ 109.7 = 41.5\ ppm$$

So, if the actual concentration exceeds this level, the more control measures be needed. So, for mixture of the vapor individual species, the TLV in the mixture are significantly reduce from the TLVs of the pure substances.

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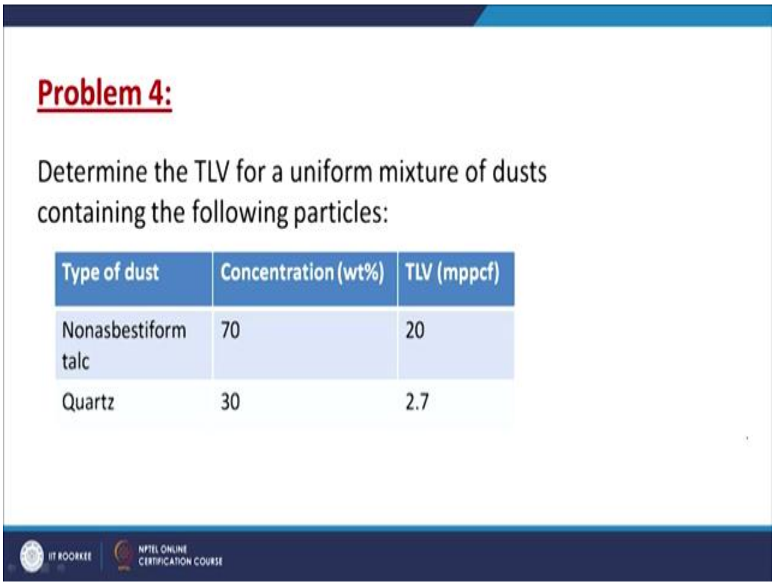

Now, let us have a look about next problem that is a problem number 4. Now, here you need to determine the TLV for uniform mixture of dust containing the following particles like Nonasbestiform talc that is a concentration on the weight percent basis is a 70 percent and TLVs given 20 mppcf and the Quartz it is having the concentration of 38 percent and TLVs 2.7.

So, the dust evaluation calculation usually are performed in a manner identical to that use for the volatile vapors which we have used in the last problem, but instead of using the ppm as a concentration of the unit milligram per meter cube or millions of particle per cubic food is more convenient.

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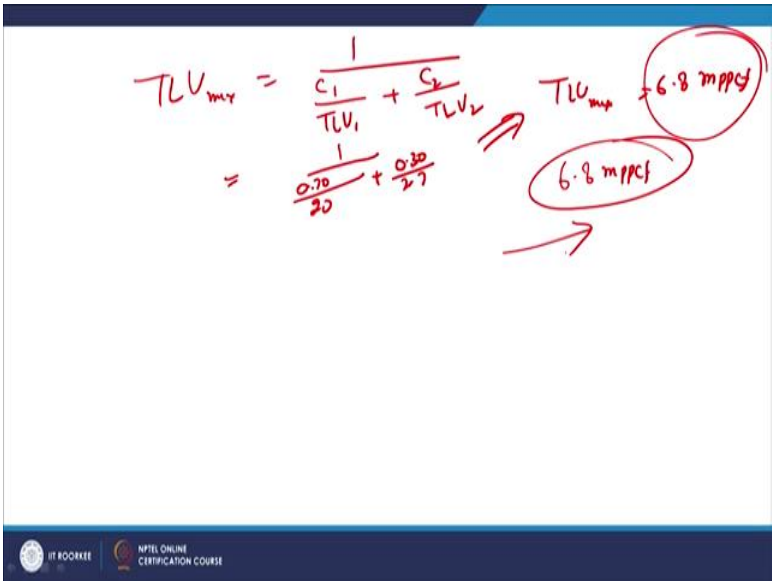

So, let us solve this particular problem,

$$TLV_{mix} = \frac{1}{\frac{C_1}{TLV_1} + \frac{C_2}{TLV_2}}$$

$$TLV_{mix} = \frac{1}{\frac{0.70}{20} + \frac{0.30}{2.7}} = 6.8$$

Now, special control measures they are required when the actual particle count of the size range specified in the standard or by the industrial hygiene exceeds this particular limits, so 6.8 mppcf is the controlling, so you need if it crosses with this particular value then you need to take the appropriate measures to counter this aspect.

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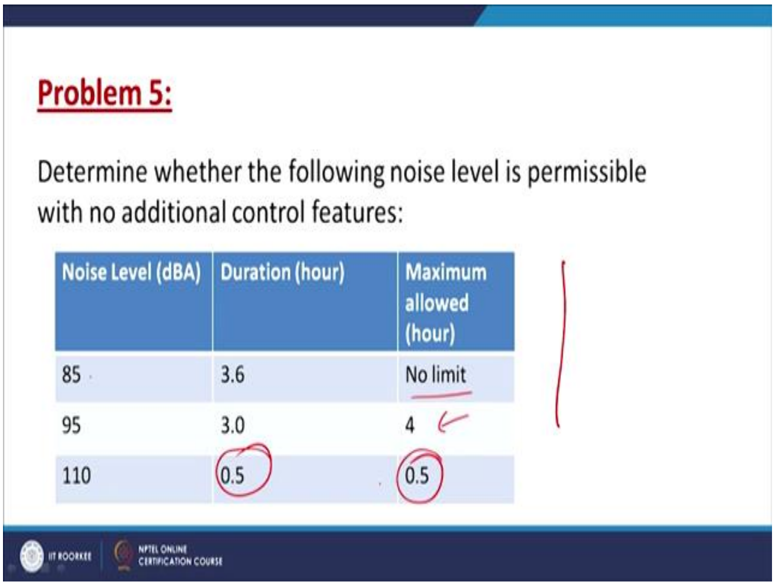

Now, let us have a look about the problem number 5, here you need to determine whether the following noise level, this one is given that is permissible with no additional control features. So, the noise level 85 decibel, the duration is given, the exposure duration is given 3.6 hours and maximum allowable duration, there is no limit for this one that means it is a safer one, 95 decibels, the duration is of exposure is 3 hour and the maximum allowed hours they are given 4 and 110 decibel the duration is given 0.5 and the maximum allowed hours they are subject to 0.5. So, let us have the solution of this particular problem.

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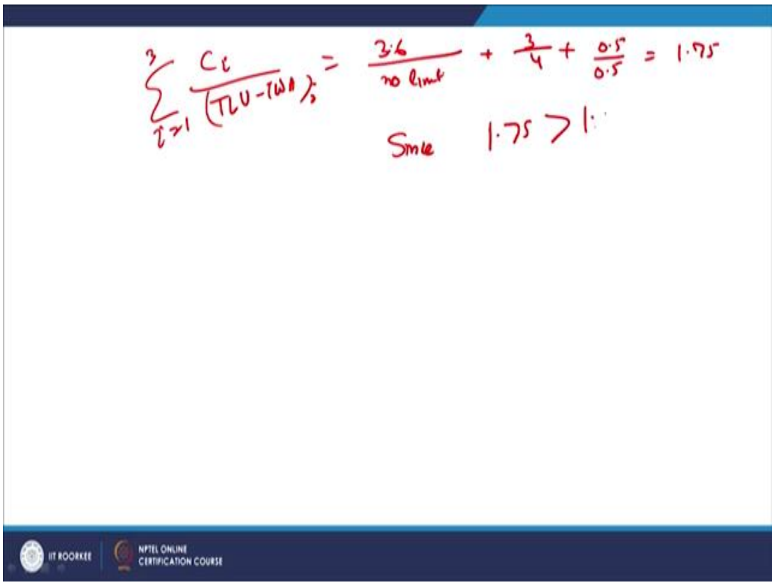

Now, from this (eq) from the equation,

$$\sum_{i=1}^{n} \frac{C_i}{(TLV - TWA)_i} = \frac{3.6}{no\ limit} + \frac{3}{4} + \frac{0.5}{0.5} = 1.75$$

Now, since this 1.75 exceeds 1.0, so employees under this environment are immediately required to take the necessary step and this may be by the use of wearing of ear protectors, etc.

So, on a longer term basis, the noise reduction control methods should be developed or deployed within (the work) the work place for specific pieces of equipment with those who are having the excessive noise levels. So, this helps us to give the proper guidelines or advisories.

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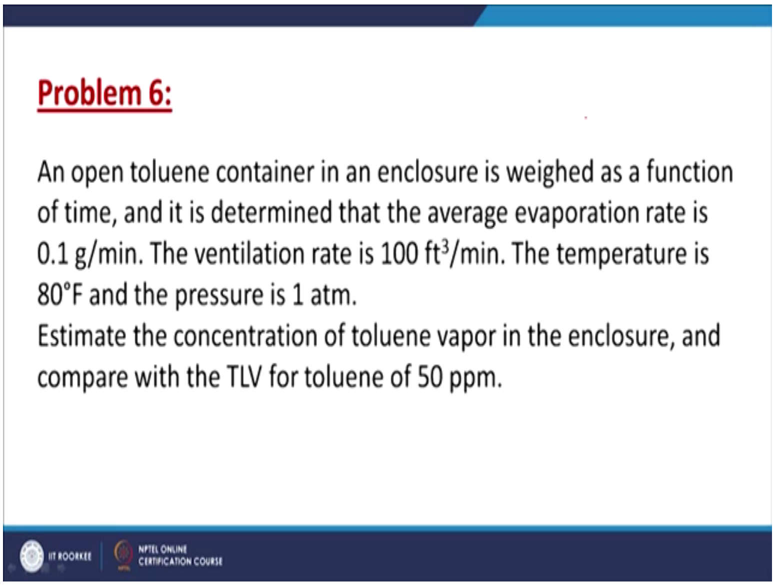

Now, let us have a look about the problem number 6. Now, this problem suggests that an open toluene container in an enclosure is weighed as a function of time and it is determined that the average evaporation rate is 0.1 gram per minute. The ventilation rate is given as 100 cubic feet per minute and the temperature is 80 degree Fahrenheit and the pressure 1 atmosphere. So, here you need to estimate the concentration of toluene vapor in the enclosure and compare with the TLV for the toluene of 50 ppm.

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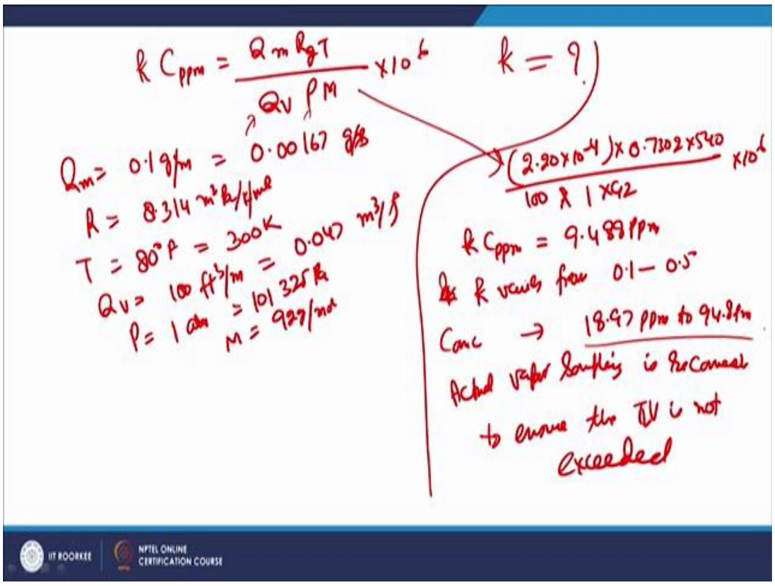

So, let us have a look about the solution of this particular problem, earlier in the theoretical module we have devise this particular formula:

$C_{ppm} = (Q_m R_g T / k\ Q_v\ P\ M) \times 10^6$

Now, here the this is the mass flow rate, the concentration and parts per million, this is Q v is the ventilation rate, P is the pressure, M is the molecular weight, R is the guess constant, T is the temperature. Now, because the value of k is unknown, so and it must be used as a parameter.

So, we are having the data with us like Q_m is equal to 0.1 gram per minute that is equal to 0.00167 gram per second, consistency of the unit is extremely important, so R is equal to 8.314 meter cube Pascal k mole, T is 80 degree Fahrenheit it is comes out to be 300 kelvin, Q_v is given that is 100 cubic feet per minute which is coming out to be 0.047 meter cube per second, P is equal to 1 atmosphere which is 101 325 Pascal and M is 92 grams per mole that is the molecular weight.

Now, if we substitute to the into the equation of to this equation, we have

$k\ C_{ppm} = (2.20 \times 10^{-4} \times 0.7302 \times 540 / 100 \times 1 \times 92) \times 10^6$

$k\ C_{ppm} = 9.488$ ppm

Now, because k varies from 0.1 to 0.5,

so the concentration is expected to vary from 18.97 ppm to 94.8 ppm. So, actual vapor sampling is always recommended to ensure that the TLV is not exceeded. So, this is then advisory for this particular problem because you are having the range of 18.97 ppm to 94.8 ppm.

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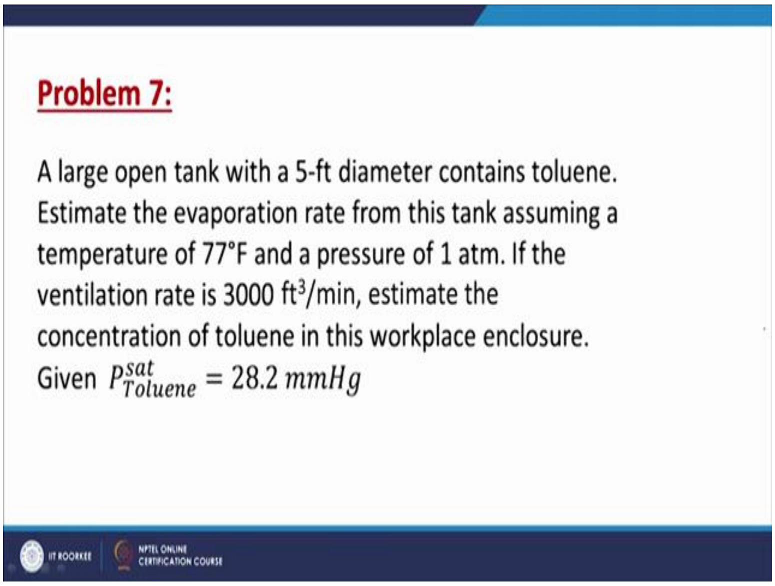

Now, let us have another problem that is problem number 7. Now, here a large open tank with 5 feet diameter, it contains toluene. Here, you need to estimate the evaporation rate from this tank assuming a temperature of 77 degree Fahrenheit and a pressure of 1 atmosphere. Now, if the ventilation rate is 3000 cubic feet per minute we need to estimate the concentration of toluene in this workplace enclosure, you are given with the saturation pressure of toluene is 28.2 mm Hg.

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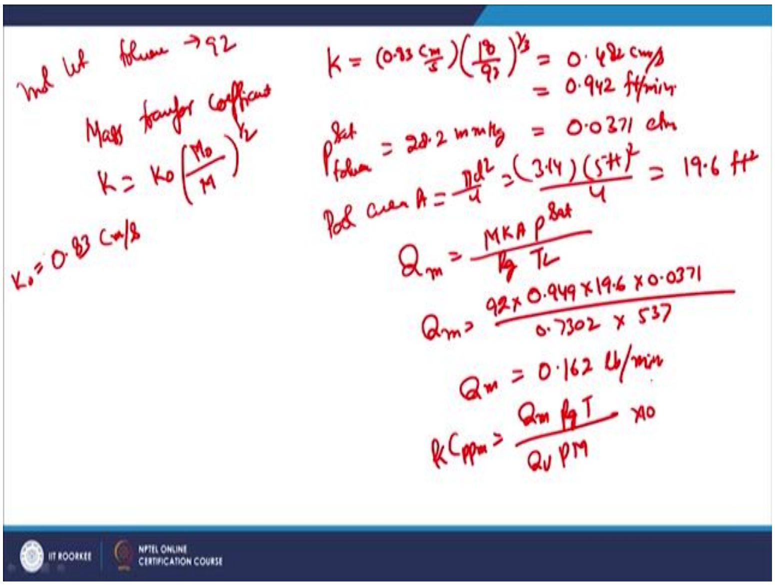

So, the molecular weight of toluene is 92 and the mass transfer coefficient, you can estimate from

$$K = K_o \left(\frac{M_o}{M}\right)^{\frac{1}{3}}$$

Now, water we are using most frequently as a reference substance, so it has the mass transfer coefficient of 0.83, so,

$$K = 0.83\frac{cm}{s}\left(\frac{18}{92}\right)^{\frac{1}{3}} = 0.482\ cm/s$$

or 0.949 feet per minute, consistency of unit is extremely important.

Now, the saturation vapor pressure which is given in the problem of toluene is 28.2 mm Hg which is 0.0371 atm. So, the pool area, we can gave that pool area

$A = \pi d^2/4 = 3.14 \times 5^2 / 4 = 19.6$ square feet.

So, you can calculate the evaporation rate by

$$Q_m = \frac{MKAP^{sat}}{R_g T_L}$$

Now, if you substitute the values because k we have already determined, P saturation which we have already determined, so if we substitute all the values,

$$Q_m = \frac{92\ X\ 0.949\ X\ 19.6\ X\ 0.0371}{0.7302\ X\ 537} = 0.162\ lb/min$$

So, you can calculate the concentration through this formula:

$$k\ C_{ppm} = \frac{Q_m R_g T}{Q_v P M} \times 10^6$$

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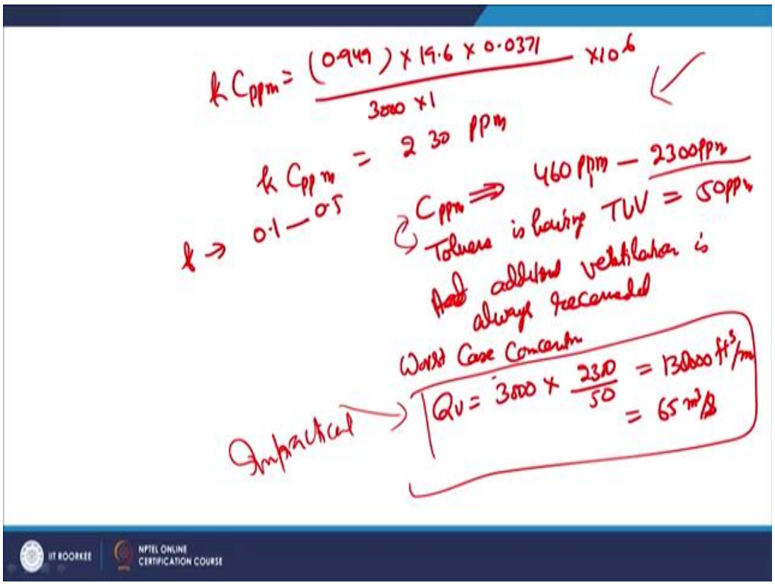

Now, if you substitute the things into the equation then we will have,

$$k\ C_{ppm} = \frac{0.949\ X\ 19.6\ X\ 0.0371}{3000\ X\ 1} \times 10^6 = 230\ ppm$$

Now, because k varies from 0.1 to 0.5, so concentration is C ppm is expected to vary from 460 ppm to 2300 ppm. Now, toluene is having TLV is 50 ppm, so additional because this always vary with this 50 ppm, so additional ventilation is always recommended.

Now, the next aspect we need to find out, the amount of ventilation required to reduce the worst case concentration, so worst case concentration suggests that we are having 2300 ppm, so,

Q_v = 3000 X (2300/50) = 138000 ft^3/min = 65 m^3/s

So, this always represents some impractical level of general ventilation.

So, you need to take the corrective measures to avoid the generation of (toluene particle) toluene vapors at workplace. So, this is always I mean remember that this gives you an opportunity because sometimes if it is impractical then you need to take the corrective measures to overcome such scenario. So, in this particular module we have discussed several problems related to industrial hygiene and we cover all the aspect in with respect to that numerical approach of this particular chapter.

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And further if you wish then we can have a refer to the references which are listed in this particular slide, so thank you very much.