Health, Safety and Environmental Management in Offshore and Petroleum Engineering
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Module – 03
Accident modeling, risk assessment and management
Lecture – 06
Fire and explosion prevention – I

Friends welcome to the 6th lecture on HSE practices.

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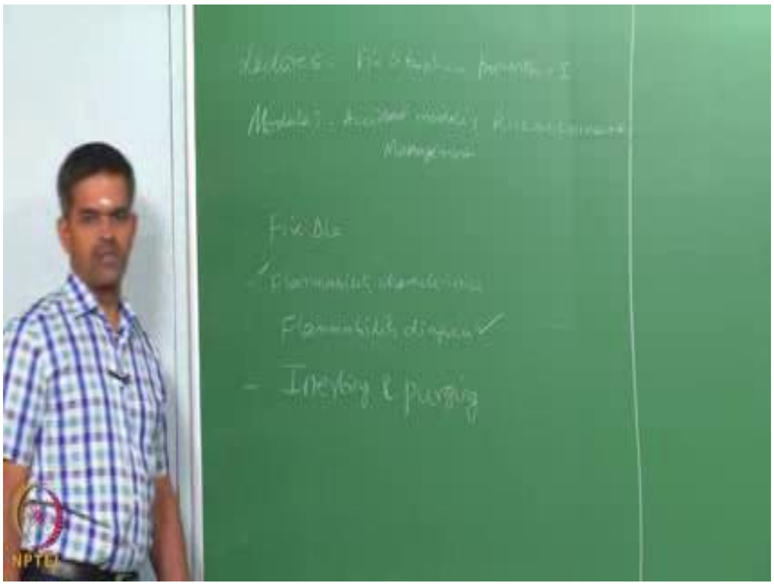

In this lecture, in module 3 where we are focusing on accident modeling and risk assessment and management, we will talk about fire and explosion prevention. In the last couple of lectures, we discussed about the requirements and characteristics of a fire triangle. We also discussed about different flammability characteristics of hydrocarbons. We have also said how using this flammability characteristics one can plot what is called flammability diagram and this diagram can be also used to actually apply this as a tool for fire and explosion prevention, which we will discuss in the present lecture.

There are many methods by which fire and explosion can be prevented. The basic idea is to reduce the concentration of any one of the arm in a given fire triangle. So, generally we call this as inerting and purging process - inerting and purging actually aims to reduce oxygen content.

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The basic objective of inerting and purging; aim of inerting and purging is to reduce oxygen or fuel concentration. The moment I say fuel concentration then I should reduce it in such manner that the target value or the flammability limits, or either about the u f l or below l f l. So, that the mixture does not catch fire. To do this, we generally use inert gasses. There are different types of inert gasses which are commonly used in the process industries nitrogen, carbon dioxide or a common choice out of which people generally prefer nitrogen.

Generally, the concentration of nitrogen used in purging operation is to establish a control point of 4 percent below in the limiting oxygen concentration, you bring down the LOC in such manner, by adding nitrogen purging that you bring down LOC by about 4 percent below the limiting oxygen concentration. Therefore, the fuel mixture cannot or is not capable of catching fire.

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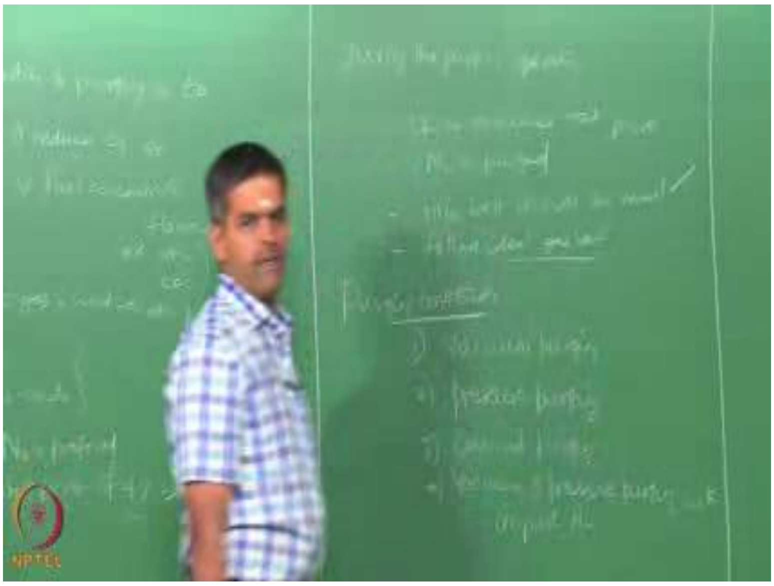

Now, interestingly during the purging methods or purging operation, it is assumed that pure nitrogen is purged. The idea is, if it is so it can mix well inside the vessel that is one advantage. You have the second advantage is it follows ideal gas flow p b is equal to r t that ratio is assumed to be followed as an ideal gas flow. So, generally out of the two inert gases commonly used in process industry, nitrogen is preferred the aim is to bring down the limiting oxygen concentration by about 4 percent, what we call as the control point. There are common purging methods which are actually used in oil industries essentially in process industries vacuum purging, pressure purging, combine purging vacuum and pressure purging with impure nitrogen sweep through purging and siphon purging.

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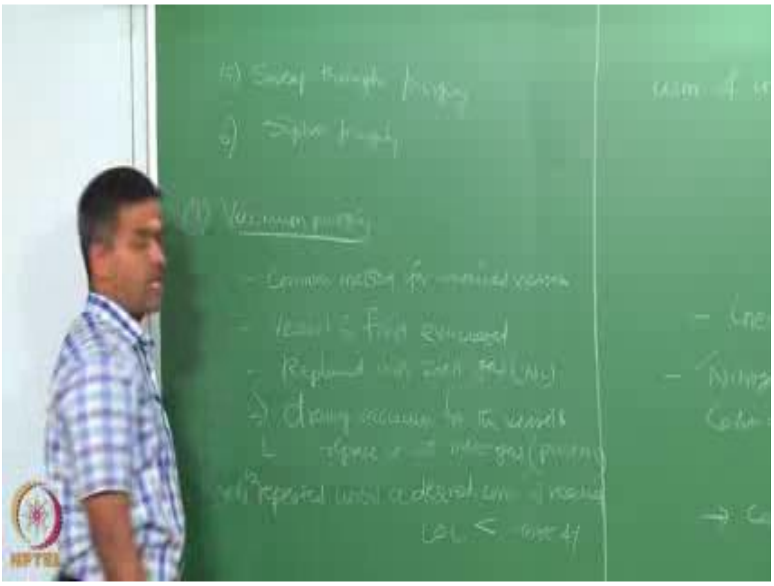

These are common methods of purging which is generally practiced in process industries like oil and gas process industries. Let us talk about vacuum purging is one of the most commonly used inerting procedure for contained vessels. So, common purging method for contained vessels in vacuum purging, the vessel is first evacuated then it is replaced with inert gas usually nitrogen. Now, once you do this the procedure includes drawing vacuum from the vessel and then replaces inert gas. So, you keep on doing this drawing vacuum from the vessel and replace it with inert gas, usually people use pure nitrogen. This cycle is repeated until a desired concentration is reached.

What is the desired concentration? The desired concentration is the limiting oxygen concentration, it should be lowered by about 4 percent until then you have to keep on doing this cycle in sense, draw the vacuum fill with nitrogen, draw the vacuum fill with nitrogen, keep on doing this, let us try to understand this graphically.

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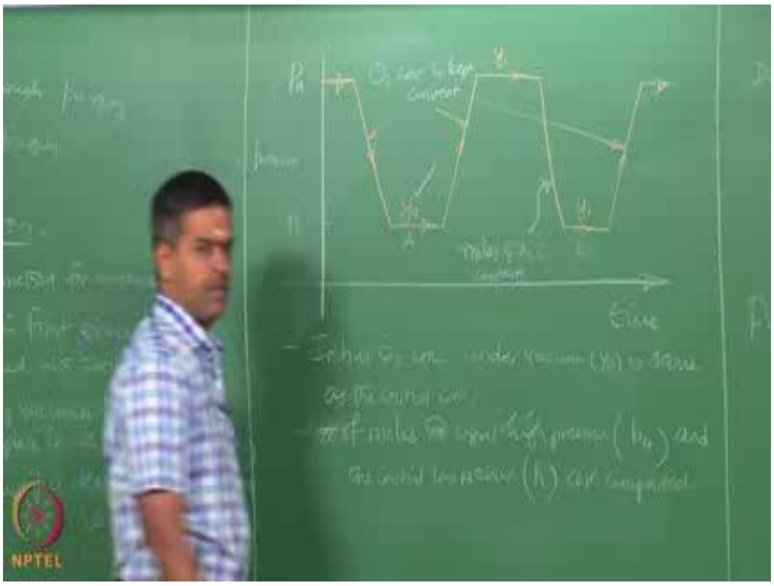

Let say over a given time, if I have two pressure indices, high pressure and let say low pressure, this is pressure. So, initially I have an high pressure, I create vacuum, lower down the pressure then maintain this concentration for some duration, I call this as y 0. Let say, this cycle or stage as a then again a pressure rise it with inert gas that is nitrogen in this case, then this concentration becomes, let say y 1 then again I vacuum and fill it up with again hydrogen, let us call this as stage B or cycle B, here the concentration will remain as y 1. Initially, it was y 0 again pressure rise it with inert gas nitrogen and keep on repeating this cycle as many number of planes until your desired concentration is reached. In the whole exercise you will see that during these stages you will see that oxygen concentration is kept constant when you release at this stage.

Let us say you will keep moles of oxygen constant having understanding this cycle and repetition of the cycle until the desired concentration level is reached. Let us talk about the concentration values of y 0, y 1, etcetera, and see what happens. So, let say initial oxygen concentration under vacuum which is y 0 is same as the initial concentration. Now, the number of moles at initial high pressure which is P H and the initial low pressure which is P L are computed, to do this people use initial equation of state for an ideal gas behavior.

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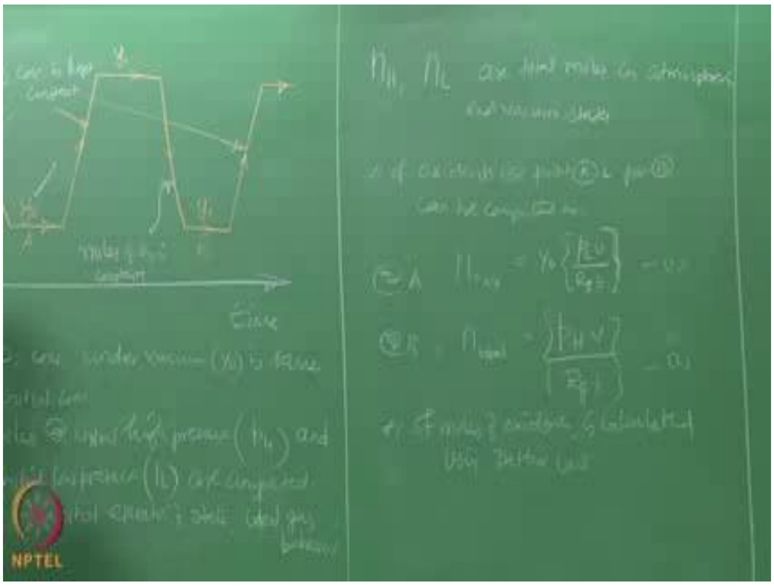

Let us say N H and N L are the total moles in the atmospheric and vacuum states respectively then the number of oxidant at point A or stage A and point B can be computed as below. So, let say at A that is stage at A here, n oxygen it will be actually equal to the concentration with P L v by R g that is gas the concentration at B will be equal to n oxygen or let say n total will be P H v by R J t equation 1, it is a equation 2. Now, the number of moles of oxygen is calculated using Dalton's law. So, the number of moles of oxidants is calculated using Dalton's law for ideal gas behavior, therefore, at the end of first cycle.

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So, you start from here; release, maintain and purge. So, at the end of first cycle new oxidant concentration becomes y 1, is it not becomes y 1, where we can say y 1 is the oxygen concentration after first purging with nitrogen. Similarly, at the end of the second cycle the concentration is expected to become y 2 and so on. Now, the interest is to compute this concentration y 1, y 2, etcetera and check them.

Therefore, y 1 is actually equal to the number of moles of oxygen where divided by the number of total which is simply y 0 P L v by R G t by P H v by R J t that is what we have here you can see here n oxygen and n total in equation 1 and 2. I substituted here which I will give get this as y 0 of P L y P H equation number 3, let say this for concentration y 1, which is the concentration of oxygen after the first cycle of nitrogen purging that some where here I want to know, compute y 2. Now, again we de pressurize and then again purge.

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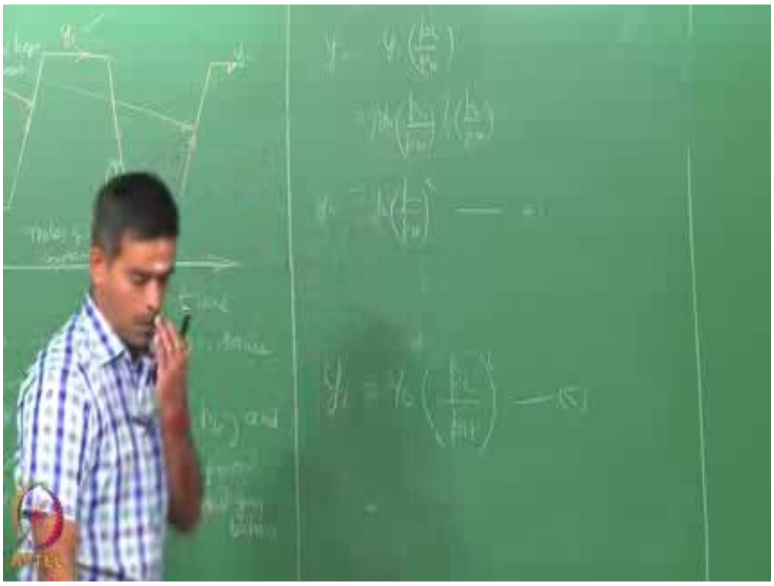

So, to get y 2, it depends upon y 1 of P L by P H y 1, we already know is y 0 of P L by P H. On the other hand is y 0 of P L by P H square that is y 2. So, I can generalize this equation for n number of cycles and say y i. Thus i th cycle it will be the initial concentration of y 0 multiplied by P H to the power i. So, in this process there is a basic assumption.

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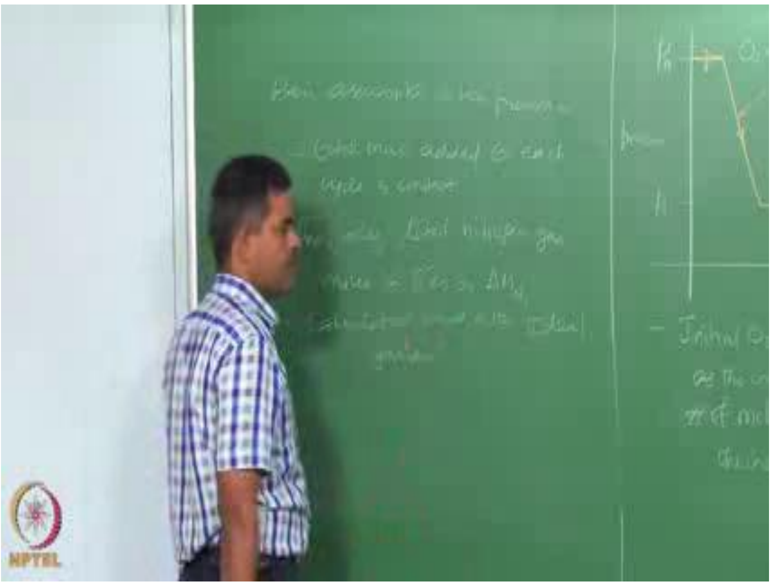

The basic assumption in this process is total mass added to each cycle is constant. Therefore, for i cycles total nitrogen gas moles is given by delta. Let say, delta n 2, which can be calculated based upon which can recalculated, based on the ideal gas law behaved, let us talk about the next method which we call as pressure purging.

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In pressure purging, vessels are pressure purged by adding inert gas under pressure. So, you add inert gas, commonly it is pure nitrogen under pressure that is why it is called pressure purging. After the gas has diffused throughout the vessel is vented back to the atmospheric pressure of fleshing. So, after the gas is dispersed or it is diffused throughout the vessel it is let out to atmosphere we call this process as fleshing.

The initial concentration in the vessel is computed after the vessel is specialized. Let say the initial concentration in the vessel which we are going to call as y 0 is computed after they were semi specialized. The number of moles at this state at the pressurize state, let us be very specific about it. At this pressurize stage which we are going to call as N H and atmospheric state as N L. Let us try to explain this graphically.

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Let say again on a time cycle, we are marking pressure let say there are two pressure values P L and let say P H. Initially, it is low you have a concentration y 0, you pressurize it and then retain for some time, you call this concentration y 1 then repeat the cycle by letting it atmosphere. Then again retain it still here also the concentration remain as y 1 then you pressurize it further. Now, the concentration becomes y 2 and so on keep repeating this and so on.

So, during these stages let say during this stage, for example, moles of oxygen will remain constant during this stage, the concentration remains constant only after it is purged, it becomes y 2. So, one can estimate the number moles in the same manner as we did for vacuum purging, the only difference here is the concentration will remain constant until the cycle is completed and then it is pressurized to get new concentration of y 2 which now depends upon the pressure difference of P H and P L at which the nitrogen gas is actually pre pressurized and purged.

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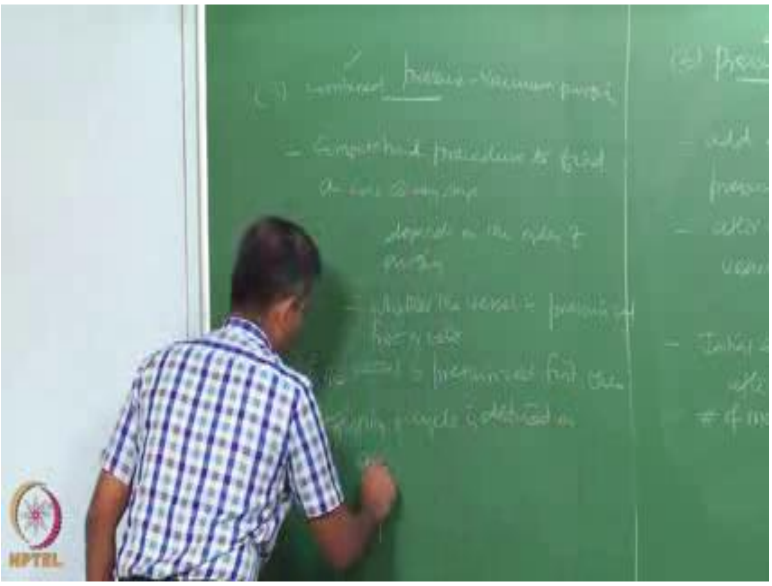

The third method by which purging is done is combined pressure vacuum purging, you combine both the operations. Now, here there is prerequisite in this method, pressure and vacuum purging are carried out to purge a vessel. The computational procedure to find concentration at any stage depends on the order of purging, that is do you first pressure or do you first vacuum? So, depends upon whether the vessel is pressurized first or later because you are going to combine this if the vessel is pressurized first then the beginning of cycle is defined as end of pressurization that is what we also did in the earlier case of pressure purging we see here.

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Now, the oxygen mole concentration at this stage remains same as that of initial mole fraction. So, no change occurs here the remaining cycles are identical to that of the pressure purge operation. As we discussed just now, if the initial concentration or initial mole fraction is 0.21, let say if the initial mole fraction is 0.21 then the oxygen mole fraction at the end of initial pressurization is given by let say, y 0 is going to be 0.21 of p 0 by P H, called equation number 6. Let i be the number of cycles of such operation of initially pressurization of initial pressurization then at i plus oneth cycle oxygen mole fraction will given by y i is equal to y 0 n l by N H of i which is nothing, but y 0 of P L by P H.

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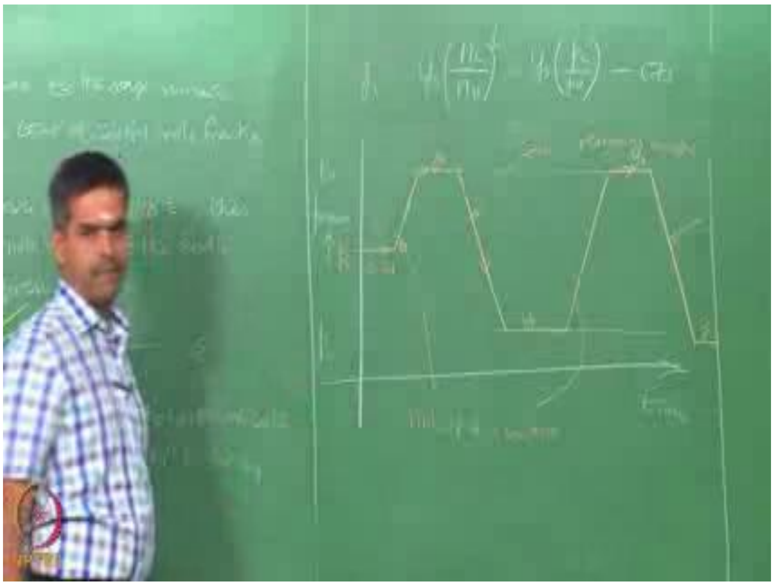

Let us try to understand this graphically, this becomes my time scale and of course, this becomes my pressure scale. These are my two bands, let say the lower pressure and high pressure, this is P L and this is P H, I take some value p 0 and the initial concentration is 0.2 then we pressurize this, maintain the concentration and call this as y 0. Then I vacuum the concentration will still remain as y 0 for some time then pressurize this. Now, the concentration becomes y 1.

So, once you get this y 1 compare to y 0 can always use the standard equations what we had in the earlier type of vessel pressure, pressure and vacuum purging to find out the concentration. So, then you will release it then the concentration still remain y 1 and the cycle keeps on continuing as you see here, interestingly moles of oxygen during these stages will remain constant, whereas at these points or at these stages concentration remains constant because it is y 0, it remains as y 0 until you pressurize it back again.

Since we start at 0.21 earlier we are using this as 0.21 as y 0 and that 0.21 happens at a specific pressure which is neither low nor high. This is a simple pressure cycle combined pressure vacuum purging.

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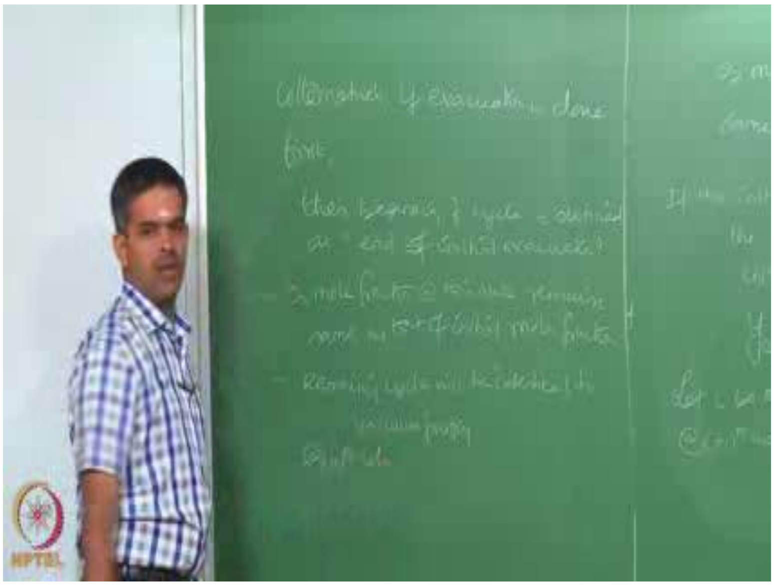

Alternatively, if evacuation is done first then the beginning of a cycle, is defined as end of the initial evacuation. Now, oxygen mole concentration or mole fraction at this state remain same as that of initial mole fraction remaining cycles are identical to that of vacuum purging. So, further remaining cycles it will be identical to vacuum purge at i plus oneth cycle oxygen concentration is given by y i is equal to y 0 N L by N H of i which is going to be same as y 0 P L by p equation number 8.

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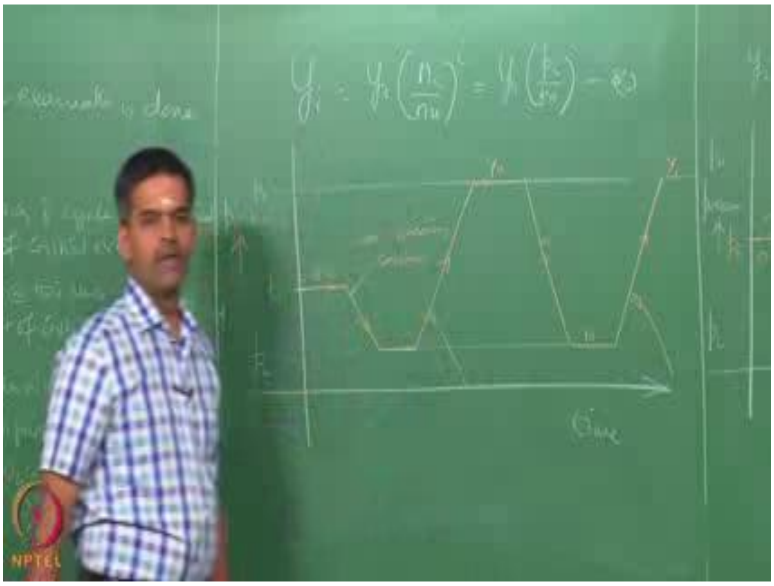

Let us explain this graphically. So, this is again the time scale; this is again the pressure scale. The limits are lower and higher, let say P L and P H, we start with p 0 at which the oxygen concentration is 0.21 fraction, you vacuum it and then retain it for some time and then pressurize it, I call this concentration as y 0 then vacuum it, retain it and pressurize it, it goes like this number of cycles. So, now the concentration here becomes y 1 and of course, the concentration here remains y 0 which means that during this stage concentration remains constant because is y 0, here y 0 here as well where as during these stages moles of oxygen is constant .

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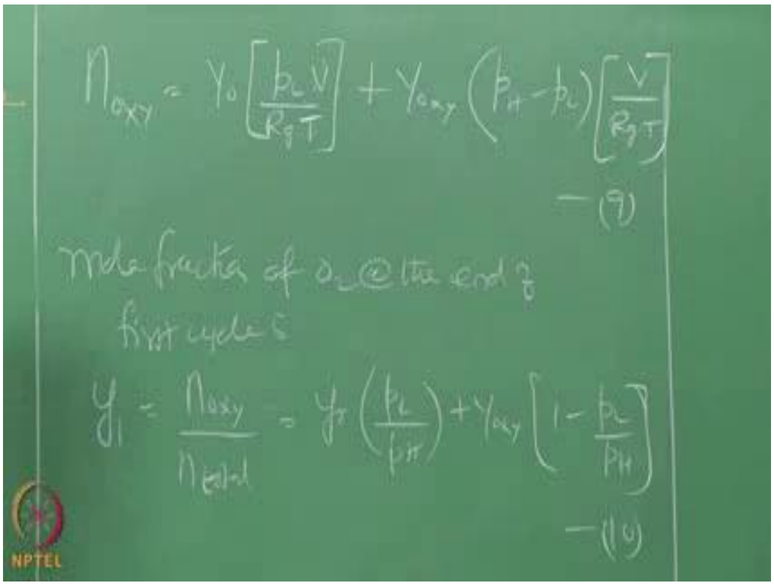

One can also do pressure and vacuum purging with impure nitrogen. So, far we have been talking about pure nitrogen purging. For a pressure purging, the total moles of oxygen at the end of the first pressurization is given as a sum of moles that are initially present and the moles included with the nitrogen. So, a number of moles of oxygen which is required is given by a simple expression which is y 0 which is P L v by R G t, let say R G t plus y of oxygen of the pressure difference between the initial and higher multiplied by v by R G t, this is the equation number 9. Now, the mole fraction of oxygen at the end of first cycle is given by let say, y 1 which is n oxygen which you compute of equation number 9 divided by n total which is simply y 0 P L by P H plus y oxygen 1 minus P L by P H, equation 10 generalizing the above equation because this is for end of the first cycle.

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So, y 1 generalizing it, we can say y 1 is y i minus 1 of P L by P H plus y oxygen of 1 minus P L by P H. So, therefore, y 1 minus y i minus 1 is simply P L by P H of i, y 0 minus y oxygen equation number 10 or equation number 11. So, if you want to really compare the pressure and vacuum purging one can give some comments on this.

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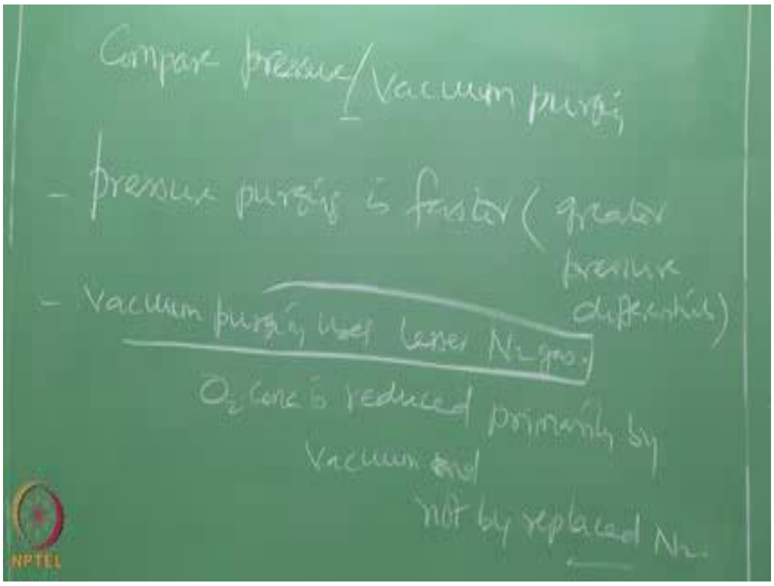

Let us try to compare pressure and vacuum purging because of greater pressure differentials pressure purging is faster, what is the reason because of greater pressure differentials vacuum purging uses lesser inert gas lesser inert gas because the oxygen concentration is reduced, that is the aim primarily by vacuum that is reason primarily by vacuum and not by replaced nitrogen. Therefore, the hydrogen gas concentration used in vacuum purging is lesser. So, one can say it is economical the further methods. We will discuss in the next lecture and we move on to the remaining methods of explosion proof etcetera.

So, friends in this lecture, we learnt about different methods of inerting and purging techniques. We have understood how to compute the concentration at n number of cycles? What are the merits and demerits of comparing two methods of purging and combine them, if you use pressurization first or if you do vacuum first and later pressurization then the number of moles actually involved and the consumption of nitrogen involved is different. Of course, the number of cycles can also be reduced if you pressure first compare to the vacuumization first and so I hope you are able to understand the application of inerting and purging techniques as one of the important methods of fire and explosion protection, or let say device methods to control them. We will also use flammable diagrams to understand, how the explosion and fire can be prevented with flammability characteristics of the given hydrocarbon.

Thank you very much.