Health, Safety and Environmental Management in Offshore and Petroleum Engineering

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Module – 03
Accidental modeling, risk assessment and management
Lecture – 07
Explosion prevention

Let us look at the 7th lecture in module 3.

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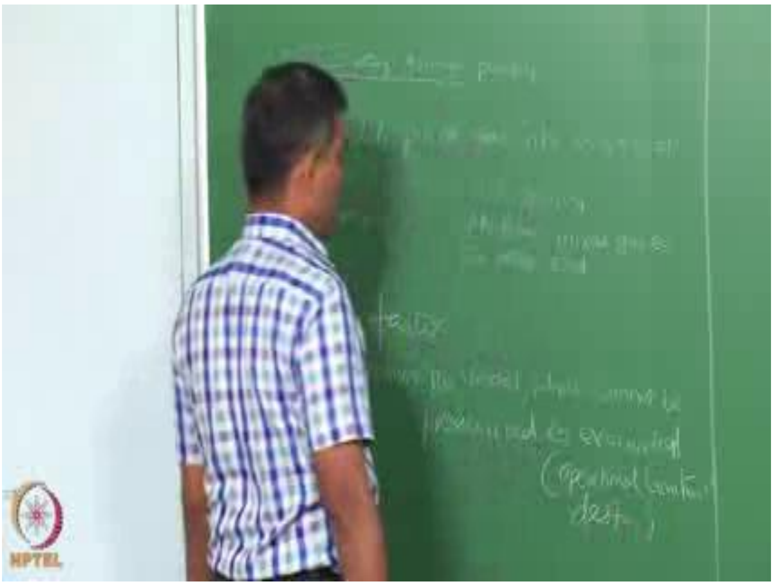

We will further discuss about the explosion prevention methods. In this lecture, we already said that purging can be done by many number of methods. In the last lecture, we will continue to discuss; the remaining two methods of purging. Then we move on to use of flammability diagram as an explosion prevention tool. So, we said that sweep through purging is also another method by which I can do the fire and explosion prevention. This purging process actually adds purge gas into a vessel at one opening. Let us say the gas added at one opening and withdraws the mixed gas at the other end that is why is called sweep through and both these operation happens at atmospheric pressure which we can see in the general figure. So, kindly pay attention to the figure shown on the screen now.

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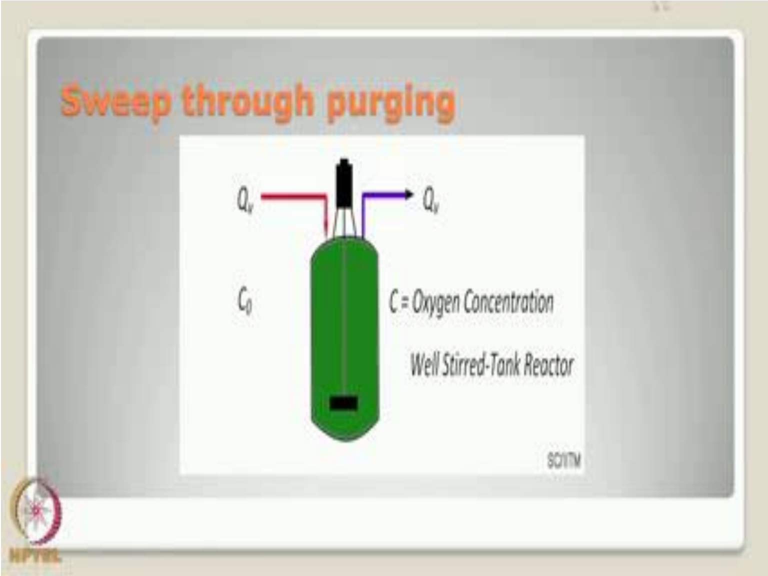

The vessel is shown in green colour and the system through which the gas or the purging gas entered and exit is what to shown in this level here. So, from one end the purging gas allowed inside and parallel from the other end the mixture is evacuated at C O is what we call Oxygen Concentration which is measured at any instant of time, since the mixed gas should have a good mixture with that of the inert gas or the purged gas. We also have a constant stirrer in the tank which continues to mix the purging gas with that of the mixture available inside the cylinder. So, that the complete purging gas replaces the entire content.

So, in the earlier cases what you saw is you evacuate the container at a low pressure, then pressurize it or at atmospheric give specific mole fraction of oxygen pressurize it and then evacuate it as number of cycles. So, that process seems to be time delay and it is slightly expensive because the quantity of purging gas being used depends on the process or the order by which you keep on purging and inerting, whereas in sweep through purging though initially, it appears as if the quantity of the nitrogen required for purging is much more than the remaining methods, but this method of purging makes it very fast, it is faster, it is actually used when the vessel is not rated for pressure or vacuum that is very, very important, when you have a vessel which cannot be pressurized or evacuated because of some operational limitations or because of designed conditions then in that case you can go for a sweep through purging.

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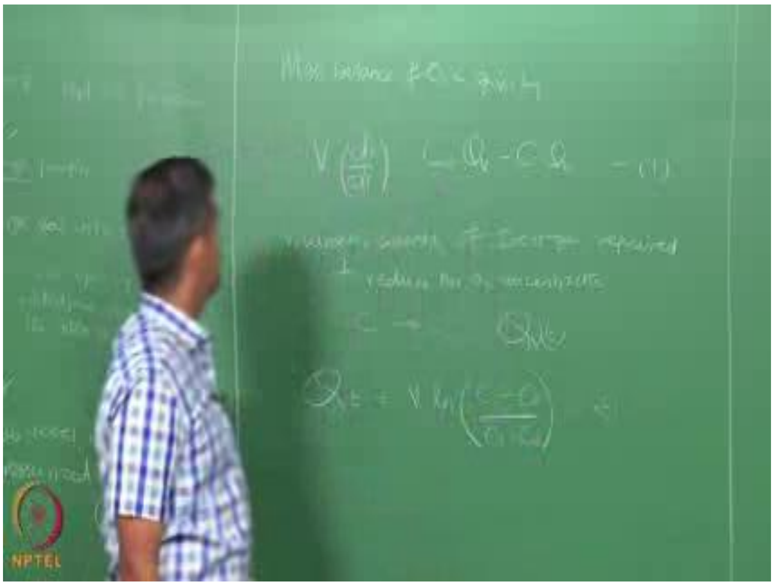

Now, the mass balance of oxygen is given by V of d c, the rate of purging which is C O Q V minus C Q V equation number 1; obviously, one can see that the volumetric quantity required reducing the oxygen concentration. The volumetric quantity of inert gas required to reduce the oxygen concentration the whole objective is to reduce the LOC concentration by about 4 percent. So, the concentration initially C, one you want to reduce it to C 2, let us say which is given by Q V of t which we get as the equation number one. So, therefore, Q V of t is then given by v of natural logarithm of c, 1 minus c dot by c 2 minus c dot.

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The other kind of purging operation which people generally do in process industry is called siphon. Purging sweep through, purging has one main demerit sweep through purging requires high quantity of nitrogen therefore, one can say this is expensive compared to the vacuum and pressure purging especially because more expensive when it is done in large volume or cylinder of large volume it becomes expensive.

In such cases, alternatively siphon purging is done. Interestingly, siphon purging is done to vessels which cannot be pressurized and cannot be evacuated. So, it is an alternative arrangement where the nitrogen consumption can be comparatively lower with that of the sweep through purging. Purging process starts with filling the vessel with liquid which is preferably water. So, initially the vessel is filled with some liquid essentially or preferably it is water therefore, purging process starts with filling the vessel with liquid not with nitrogen as in the case of sweep through purging purged gas is subsequently added to the vapor space as liquid is drained off from the vessel.

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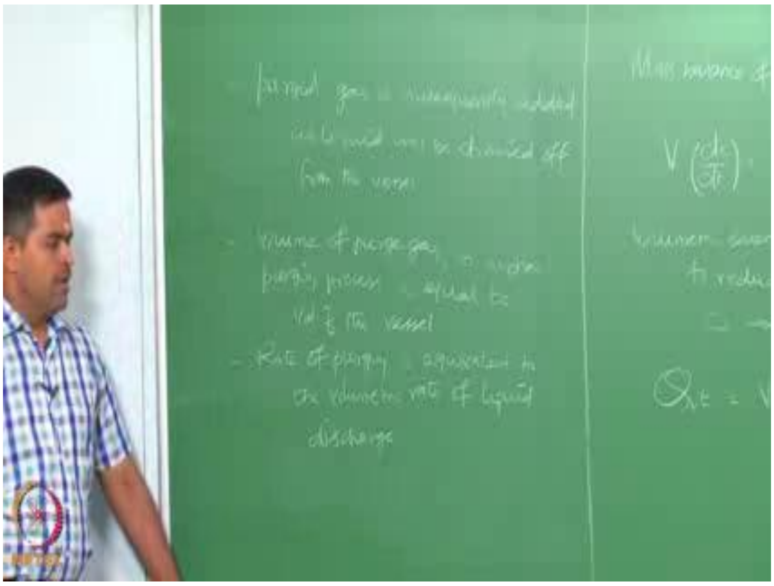

Now, interestingly volume of purged gas used in this case is actually equal to volume of the vessel because it is actually essentially replacing the liquid inside the vessel therefore, the rate of purging is equivalent to the volumetric rate of liquid discharge. So, friends one of the effective method of exploration prevention is inerting and purging.

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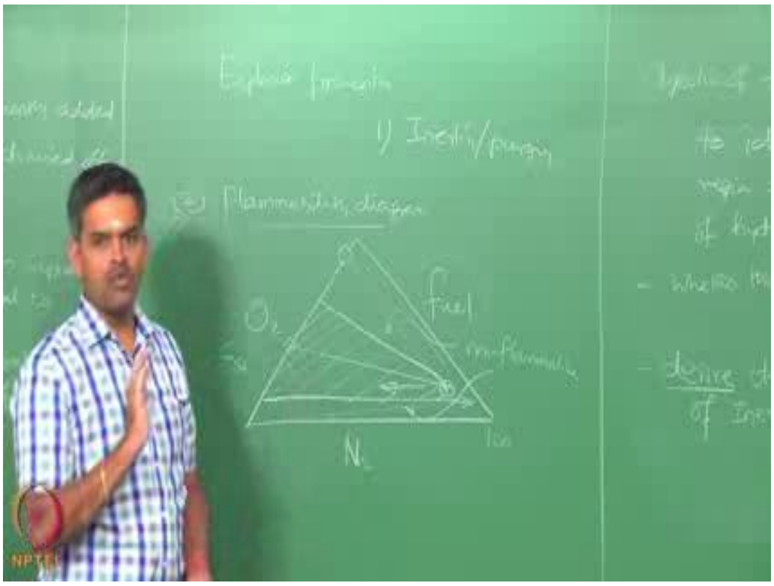

One method is what we saw inerting and purging. The second method could be one can also use effectively the flammability diagrams. Let us recollect the flammability diagram, it is actually representation of the fuel in the arm, which says if this is my flammable region, if the fuel concentration or the flammability characteristics of the fuel concentration at any instant of time does not fall in the flammable region then, one can always say the mixture will not catch fire or it will not catch any resulting in an explosion.

So, one can also use effectively the flammability diagram to alter the flammability characteristics or the fuel mixture in such a nice manner. So, that at any given instant of time the flammable mixture does not fall within the range of flammability of this particular mixture which is the original content or original quality of the fuel mixture.

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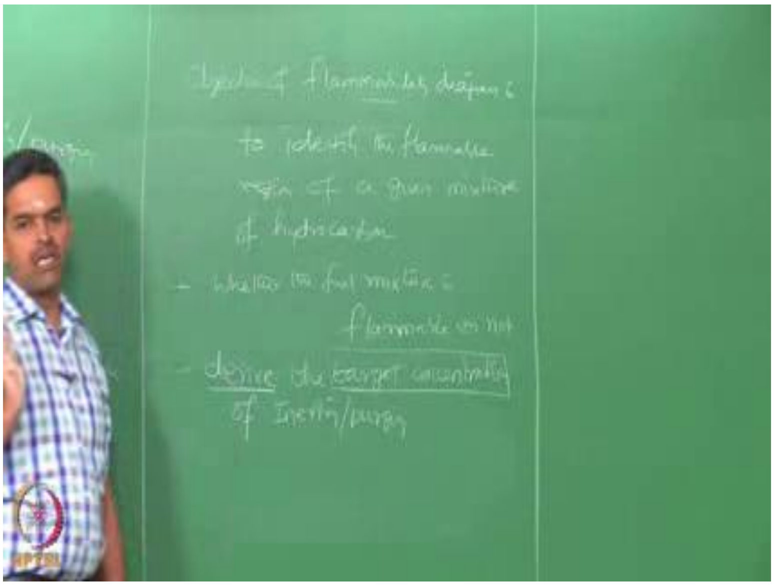

So, the main objective of using flammability diagram or let us say of flammability diagram is to identify the flammable region of a given mixture of hydrocarbon flammable diagram will tell you, whether the fuel mixture is flammable or not depending upon its flammability characteristics. Therefore, interestingly one can be able to derive the target concentration of inerting and purging, if you look back the flammability diagram very carefully here the nose of this curve is interestingly the intersection of the LOC. This is LOC and the stoichiometric balance.

The stoichiometric balance line or the stoichiometric concentration, CST depends upon the fuel mixture of hydrocarbon and the LOC line depends on what is the oxygen concentration require for the mixture to catch fire. If I am able to either lower this or reduce this, on the other hand extend this nose or contrast this nose, so that the flammability region can be reduced or compressed. So, the larger area will remain non-flammable. So, these regions are all non flammable the idea is that. So, flammability diagram can be used to derive the target concentration at which you must do the purging as we just now studied purging essentially uses nitrogen.

So, what I am essentially doing is changing the nitrogen concentration because this 0 to 100, to such a derived or such a desired order. So, that the nose of the curve or the nose of the flammability region is contrasted and the flammability region is shrunk. So, that larger area remains non flammable. Therefore, flammability diagram can be intelligently used to decide what could be the target concentration at which you must purge the given vessel to prevent fire hazards.

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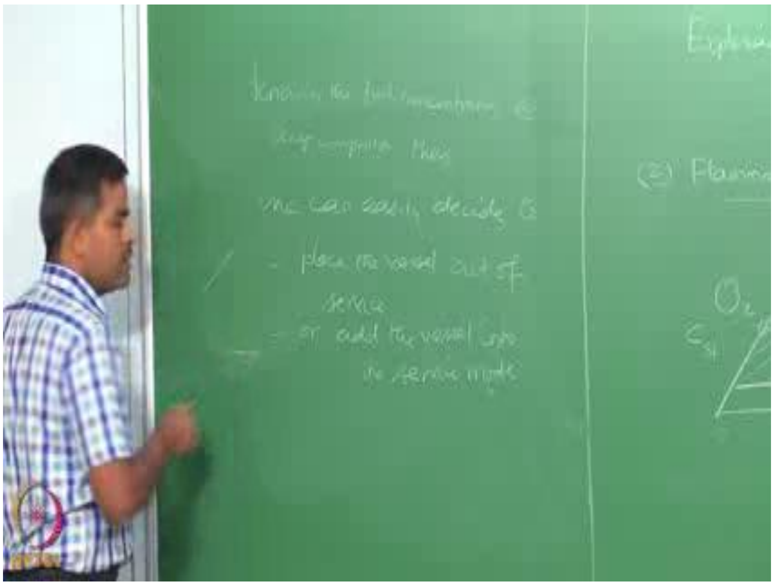

Therefore, knowing the fuel concentration at any given composition because the composition may keep on changing depending upon the operation and temperature and pressure, and we all know the flammability characteristics like upper flammability limit, lower flammability limit. These are the points, which will govern the nose area it all depends upon all their function of temperature and pressure therefore, at any given composition, if you know the fuel concentration then one can easily decide to place the vessel out of service or add the vessel into service mode. So, one can think about whether the vessel can be placed out or added in the process line. So, one can always decide intelligently the process diversions such that fire hazards for the fuel concentration at that composition can be avoided.

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Let us take for the first case placing the vessel out of service. Let us quickly see a typical flammability diagram, please pay attention to the flammability diagram shown on the screen now, which is going to be useful for discussing vessel out of service or to decide the vessel to keep it out of service.

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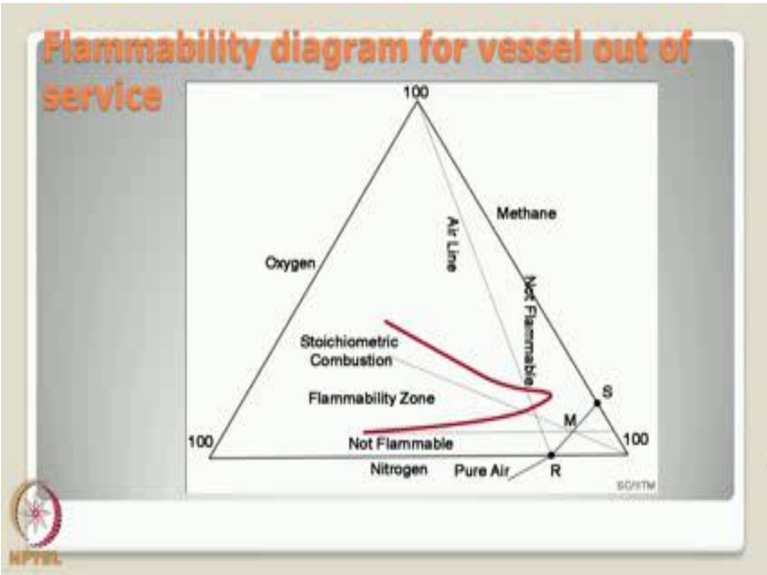

So, as we know the nitrogen arm, the fuel arm in this case it is methane CH 4 and the oxygen arm 0 to 100, 0 to 100, 0 to 100 and 0 to 100. So, cyclic I mean this is specific anticlockwise order, which may as follow to plot the flammability diagram which we discussed in the previous lectures, let us say I have drawn the air line I am able to get the nose on the curve. So, we know that this point or this region and this region are non flammable regions and the nose is decided by the stoichiometric combustion point and therefore, this region which is shown red colour is the flammability zone or flammability region.

Let us pay attention to the concentration points of R, M and S, where M, actually is the stoichiometric combustion line joining the apex of nitrogen. Let us say, the point M R is the point on the nitrogen, which is a pure air concentration and S is going to be the desired fuel mixture which is then arrived at, so that the fuel will made to remain in non-flammable region with reference to the flammability diagram. Just now we saw, let us talk about the gas concentration, gas means the purging gas, purging gas concentration at points R and M.

So, what is the points R and M, R is this point and M is this of course, S is actually the fuel mixture concentration. So, let us say we know these points let us say the gas concentration at the points R and M are known then a composition at point S, which we read is given by vessel out of service, which is given by the LFL value of the fuel mixture by 1 minus stoichiometric relationship value LFL by 21, which is equal to LOC by Z of 1 minus LOC by 21 was 89 percent. The 79 percent is generally the nitrogen concentration in pure air equation number 1 I can also do this by replacing the vessel back in service, now the fuel concentration or the fuel mixture is varied.

Kindly pay attention to the flammability diagram now drawn or shown in the screen. Let us say, we are now bothered about the concentration S depends on the varied concentration of M and R. Let us say, which is now going to again take my fuel back into the non flammable region. So, we generally do by pumping the fuel in and initially that the vessel is place out of service. So, there is no fuel entry into the vessel because the vessel can catch fire or explode because of the fuel concentration of that mixture at that instant. So, once the concentration is vary then the fuel can be allowed inside. So, I want to bring back the vessel in service. So, I pump the fuel back again, now, you can see here.

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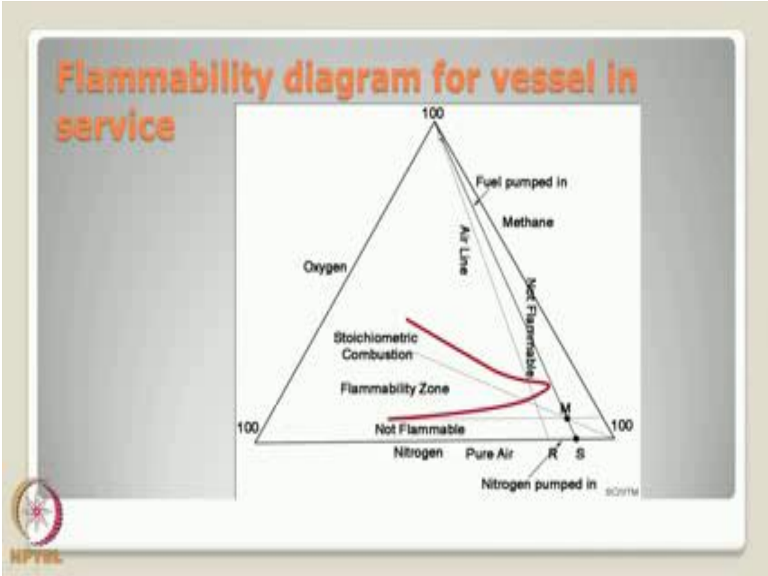

The fuel line will be now changed and a new concentration S will be decided and one can easily use this revised flammability diagram to get the concentration or composition at S. So, the composition at point S will be now given by in service vessel in service which is set into LFL by 1 minus LFL by 100, which is Z into LOC by Z minus LOC by hundred where the nitrogen concentration at the point S is actually equal to 100 minus ISOC.

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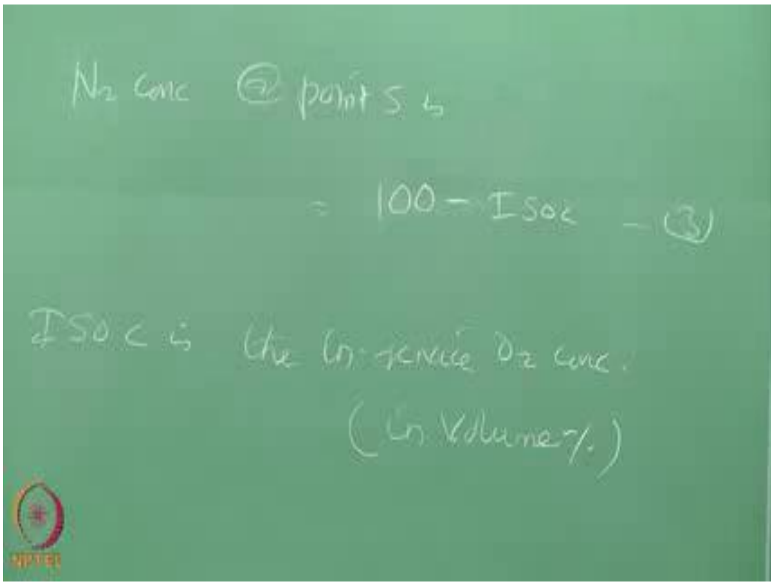

What you get from here. So, equation number 3, where ISOC is in service, the in service oxygen concentration in volume percentage expressed in volume percentage. So, the second set of methods, what we saw just now or how to use intelligently the flammability diagram to decide whether the vessel should be remained or kept out of service or the fuel or the vessel can be used into back into the service. So, by changing the fuel concentration or the mixture concentration one can always try to bring down the mixture in a non flammable region. Therefore, explosion can be avoided.

So, the first set where inerting and purging which we said about 6 methods we explained we also said what would be the required nitrogen concentration or oxygen mole fraction required to do the inerting and purging operation in the second set of discussions. We discussed about the use of flammability diagram and know the concentration of nitrogen as well as oxygen in service or out of service from the equations is given to you on the black board. The third set of recommendation is given by national fire protection authority. So, NFPA the national fire protection agencies

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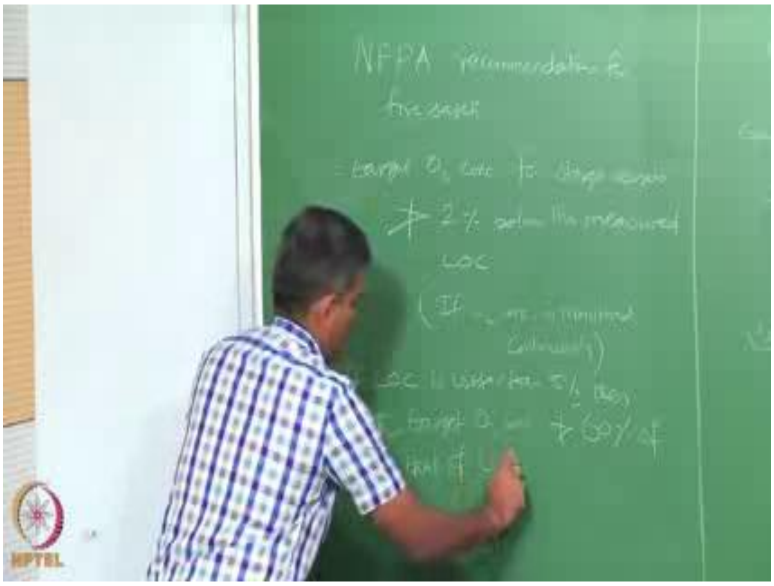

Also recommend for some conditions for fire safety, according to the NFPA recommendations the target oxygen concentration for storage vessels should not exceed 2 percent below the measured LOC. This is true only when if the oxygen concentration is monitored continuously if the limiting oxygen concentration is lesser than 5 percent, then the target oxygen concentration should not exceed sixty percent of that of LOC.

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In addition, if the oxygen concentration is not monitored continuously then the vessel or the equipment must not operate at a condition more than 60 percent of limiting oxygen concentration or 40 percent of LOC, if LOC is less than 5 percent. So, these are some of the recommendations given by NFPA very categorically by following which one can avoid fire explosions. The forth set of recommendations could be explosion proof equipments.

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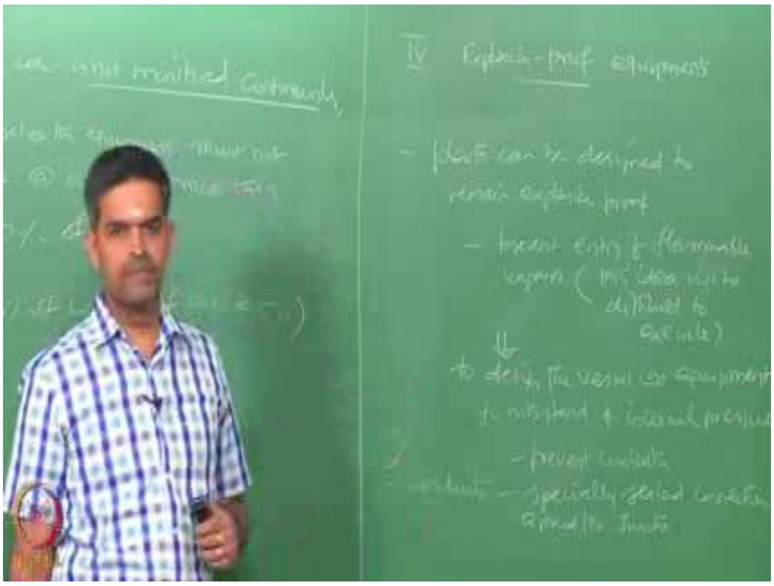

One can also look for the explosion proof, equipments plants can be designed to remain explosion proof, how they can be done? They can be designed in such a manner they can prevent entry of flammable vapors entry of flammable vapors that is very difficult to do the design this manner because it becomes difficult to design in such a manner. So, this idea will be difficult to execute hence people follow alternatively to design the vessel or equipment to withstand high internal pressure.

So, that is the common design phenomena, people generally follow to make them as explosion proof. So, that it can prevent combustion by design. So, there are some practical examples what people generally follow as explosion proof equipments one can use conduits which have specially sealed connections around the junction around the junction. So, such conduits are generally classified as explosion proof equipments. So, as you know when you really need to design the vessel or an equipment to make it explosion proof or to withstand high internal pressure, so that the combustion cannot be developed. So, explosion proof equipments are classified based on the area and material are classified.

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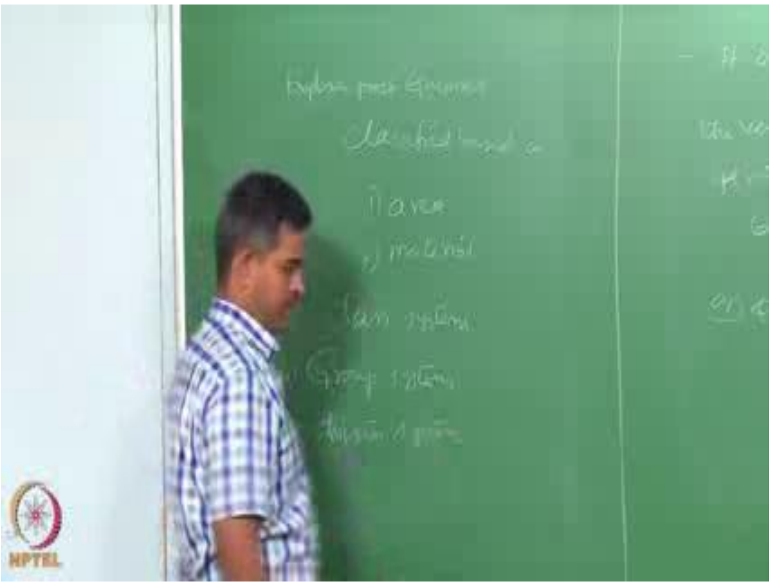

Based on the area and material used they are classified as class systems group systems and division systems.

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Let us see the class systems; class system related to the nature of the flammable material. They are related to the nature of flammable material stocked inside they are called as class 1, which refers to the locations where flammable gases are present. You can also use what we call class 2 equipments where flammable dusts are present; you can also refer a location as class 3 where combustible fibers are present. You can also say dust is also present, but not in suspension one can also talk about group systems grouping is based on the presence of specific type of chemicals is based on presence of specific type of chemical.

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They are grouped in such a manner chemicals having equivalent hazards chemicals with equivalent hazards are actually grouped. We can give example, let us say group A has chemical of nature of acetylene, group B refers to chemicals like hydrogen ethylene which has equivalent hazard level; group C refers to chemicals grouping of carbon dioxide hydrogen, sulphur, etcetera. Group D refers to chemicals like butane ethane ethyl alcohol, etcetera group E refers to aluminum dust, Group F refers to carbon black and group g refers to very fine dust which is flour.

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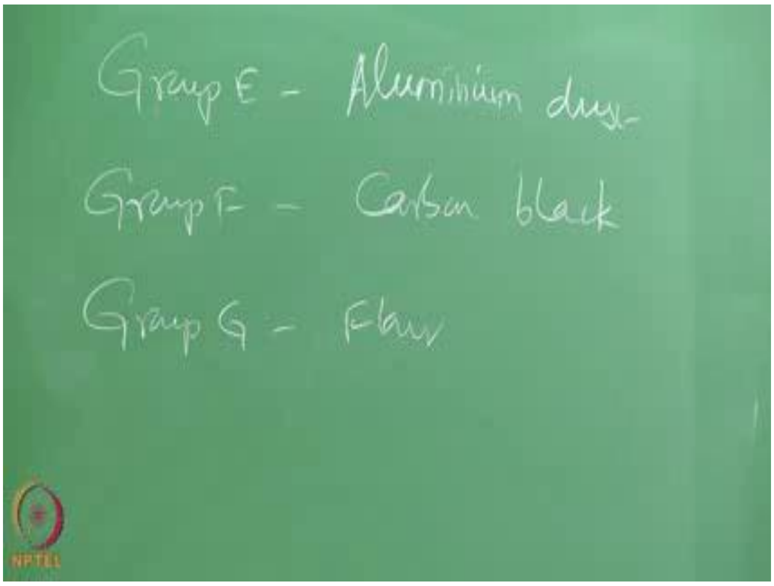

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The third classification goes as division systems divisions are actually categorized with respect to the property of material being flammable or within the explosive region. So, one can say that, let us say division one we are referred to the case where probability of ignition is very high, high probability of ignition and has high flammable concentration division two actually refers to the case where hazards can occur only at abnormal conditions. So, one can look at the division of the systems one can look at the class of the systems and one can look at the groups of the system which can be all come under one category of explosion group systems.

So, interestingly friends in this lecture, we discussed about explosion, protection essentially there are 3 or 4 systems by which this can be done one by inerting or purging. There are many methods by which this can be achieved and they are been also compared in terms of the efficiency the speed economy that is consumption of nitrogen as an inert gas, one can also use impure nitrogen in terms of pure nitrogen, when the vessel is not able to sustain the pressure or evacuation then one can go for sweep through purging or siphon purging which we discussed one can also essentially, use flammability diagrams as essential tool to decide when this purging should be done it means at what concentration of oxygen the nitrogen can be pumped in or purged out. So, whether you can place the vessel in service or out of service can be decided. So, that the fuel mixture at any instant of time does not fall in the flammable region of that particular figure.

Thirdly, one can also look at the NFPA recommendations of limiting the decrease of the maximum allowance of LOC with respect to whether the vessel is having LOC of less than 5 percent or not 4, 3, 1 can also decide by choosing proper explosion proof equipments depending upon the category and group and location and divisions depending upon what chemical you are using, what flammability the chemical has? What location you are talking about? And what kind of equivalent hazard material? We are discussing in terms of handling them for explosion proof. So, by these techniques one can easily handle a designed system, so that fire and explosion can be prevented to a larger extent which is very useful tool in oil industries especially in process plants.

Thank you very much.