Health, Safety and Environmental Management in Petroleum and Offshore Engineering

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Module No. # 04

Lecture No. # 01

Safety measures in design and process operations

Ladies and gentlemen, we have been discussing the health safety and environmental management program. Now, we are going to discuss on module four. In this module, we will discuss safety measures in design and process operation.

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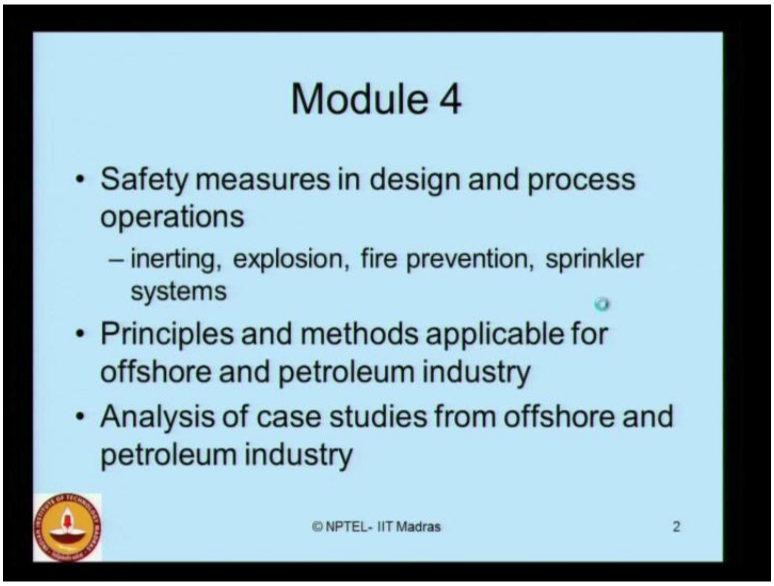

Let us see, what is the outline of module four. In module four, we will talk about safety measures in design and process operation. We will discuss inerting, explosion, fire prevention, and design of sprinkler systems effective for fire and accident processes. We will also discuss briefly, the principles and methods applicable for offshore and petroleum industry related to safety. I will discuss case studies, where I shall analyze these case studies with respect to risk analysis in the perspective of offshore and petroleum industry.

I hope, you have gone through the remaining modules earlier answered all the questions and tutorials. If you have still any doubt, you can always contact me at NP-TEL, IIT Madras.

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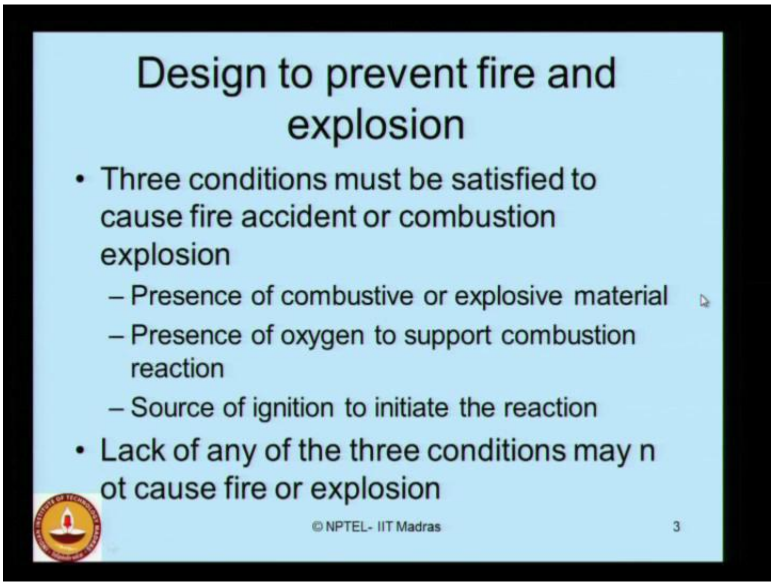

The fundamental question comes, can we prevent fire and explosion? There are many methods to do this. The fundamental technique what we will discuss here is, can we design a system which can prevent fire and explosion? For a fire accident or a combustion explosion to occur, three basic conditions must be satisfied. We have already discussed, the fire triangle in the previous module; based on that let us try to quickly revise those three conditions which are required for a fire accident or a combustion explosion to occur.

Essentially, combustive or explosive material should be present. There should be presence of oxygen to support the combustion reaction and of course, you need a source of ignition to initiate the reaction. Lack of any of the three conditions mentioned above may not cause fire or explosion. So, on the other hand, if you want to effectively design a system which can prevent fire and explosion, either you should avoid the presence of combustive material, which is practically not possible, because in offshore drilling we deal with explosive material and inventory of these in the storage and production platforms.

You can never imagine of avoiding the presence of oxygen to support the combustion mechanism, because oxygen is otherwise required for many other inherent process. By default, due to the electric processes present in an offshore and petroleum industry, source of ignition is an inherent part of the system. So, ladies and gentlemen, you can clearly understand that by avoiding any one of these three we cannot prevent fire and explosion. How can we design it effectively, that is the fundamental question which we will try to answer now.

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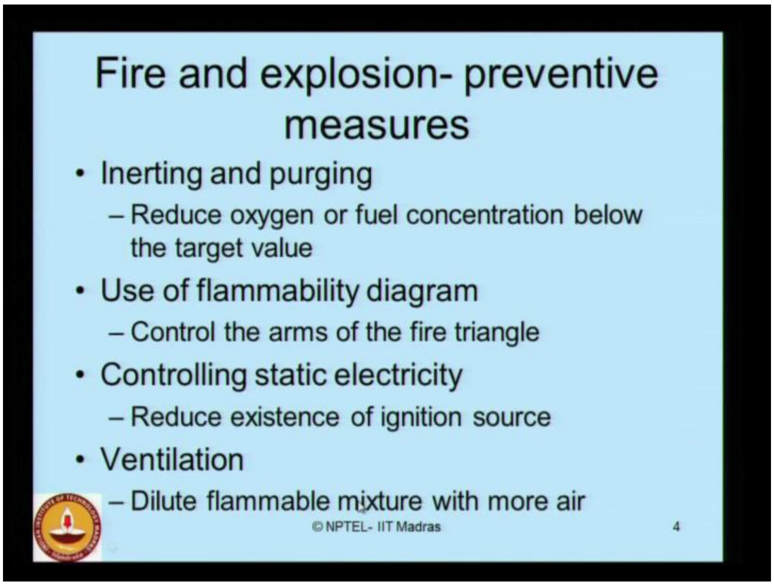

There are many preventive measures for fire and explosion. One is what we call as inerting and purging; this is a mechanism by which you reduce oxygen content or the fuel concentration below a target value. You can use flammability diagram, you can control the arms of the fire triangle to prevent fire and explosion. You can also control the static electricity present in the system. Reduce the existence of ignition source in the process system. You can also design a very good ventilation system; this will dilute the flammable mixture with more air concentration.

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There are many hazard control measures related to fire and explosion. Use of explosion proof equipments and instruments are strongly recommended as one of the effective hazard control measure for fire and explosion reductions. You can also use what we call as well designed sprinkler systems which we will discuss in the current presentation. You can also use modern design features which we will just give a brief summary of some of the tips about the modern design features.

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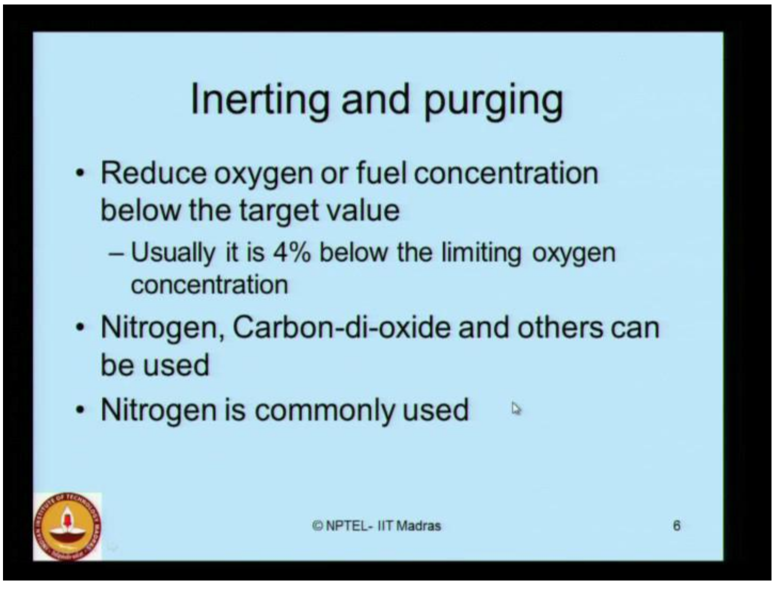

Let us discuss these processes one by one. Let us pick up the first one inerting and purging. Inerting or purging is basically a mechanism by which you reduce the oxygen concentration or the fuel concentration below a specific target value. Usually, this is 4 percent below the limiting oxygen concentration - referred as LOC in the literature. You can also use nitrogen, carbon-di-oxide for purging. However, nitrogen is commonly used in the purging process

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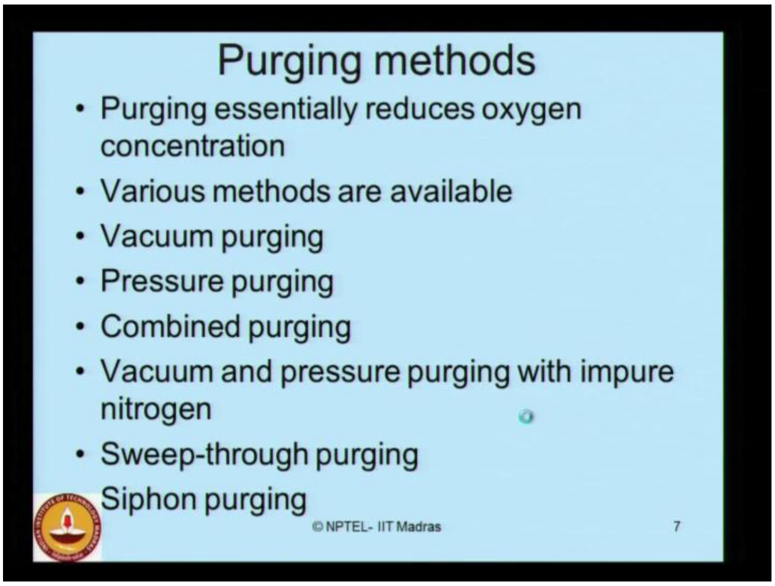

There are different purging methods which are commonly practiced in offshore and petroleum industry. As we understand, purging essentially reduces the oxygen concentration in the environment. Various methods are available for purging. We will name them one by one. The first one, what we call is a vacuum purging; the second one is pressure purging; third one is a combined purging; forth one vacuum and pressure purging with impure nitrogen, sweep-through purging, and siphon purging.

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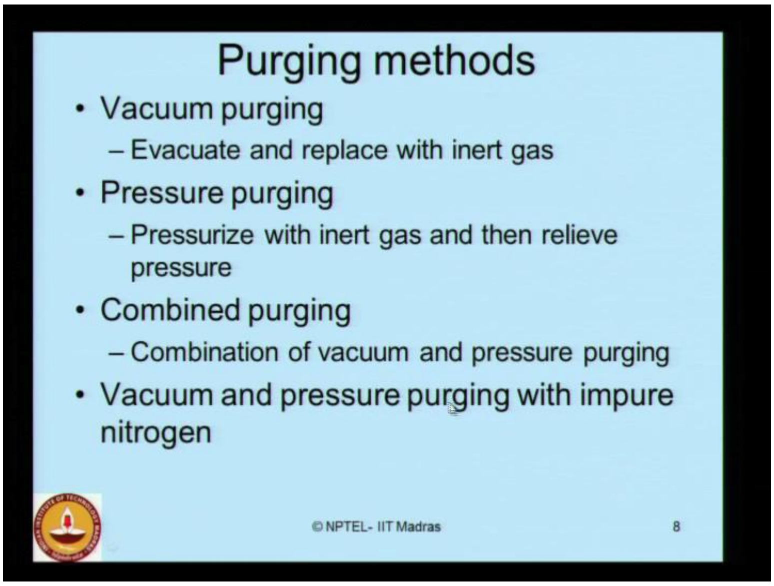

Let us talk about vacuum purging. It is a process by which you evacuate and then replace the content with inert gas. In the case of pressure purging, you pressurize the container or the containment with an inert gas and then relive the pressure inside the container or the containment. Combined purging is actually a combination of vacuum and pressure purging. You can also do vacuum and pressure purging with impure nitrogen.

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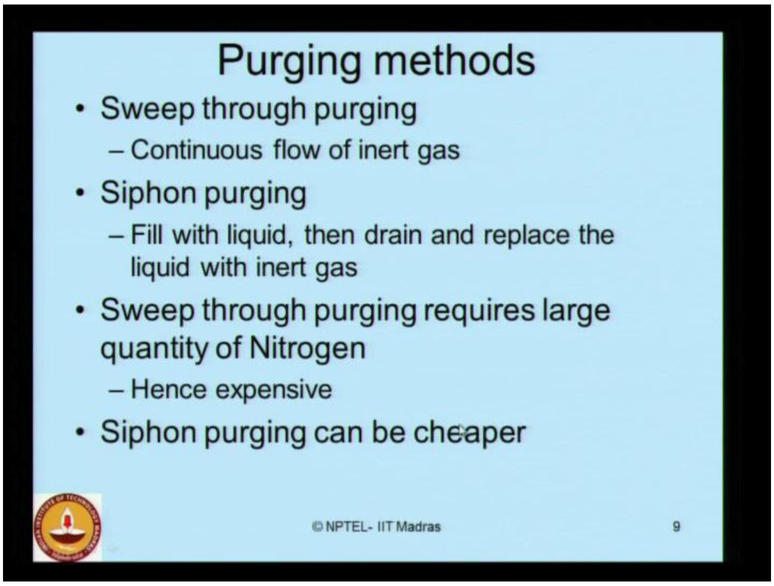

Sweep-through purging allows a continuous flow of inert gas mostly nitrogen is being used in these cases. In the case of siphon purging, we fill up the liquid in the container then drain it and replace the liquid with inert gas that is why it is called siphon purging. Sweep-through purging requires a large quantity of nitrogen and hence this is considered to be a very expensive process and it is commonly not practiced in petroleum industries. Siphon purging rather could be cheaper in comparison to sweep-through purging.

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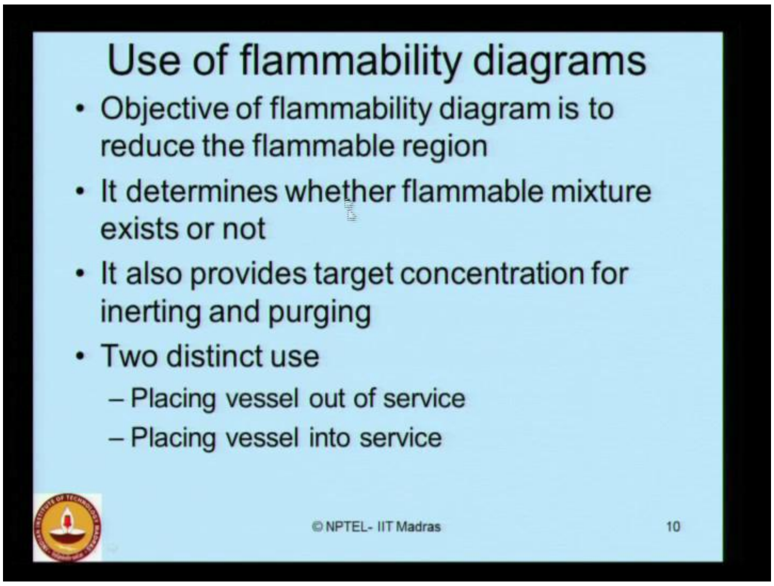

The second method by which you can control or prevent fire accidents or combustion explosion is using the flammability diagram very effectively. Ladies and gentlemen, I believe that you have understood how to plot a flammability diagram for a given fuel. What are the arms of a flammability diagram, where are these values of 0 and 100 lying on the flammability diagram, and what are the different terminologies which are related very important to flammability diagram.

Now, let us see having plotted a flammability diagram for a given fuel how can you use the diagram effectively, to prevent fire and combustion explosion. The main objective of plotting a flammability diagram is to reduce or minimize the flammable region. Ladies and gentlemen, you can easily recollect that flammable region is an intersection of basically three lines in a flammability diagram. I urge you to get back to the previous module and understand how to get a flammability region for a given fuel.

The flammability region determines whether the flammable mixture exists or not. It also provides the target concentration for inerting and purging. There are two distinct use of flammability diagram in fire prevention. One is placing the vessel out of service; one is placing the vessel into service. Let us see how I am going to use the flammability diagram for both of these applications separately.

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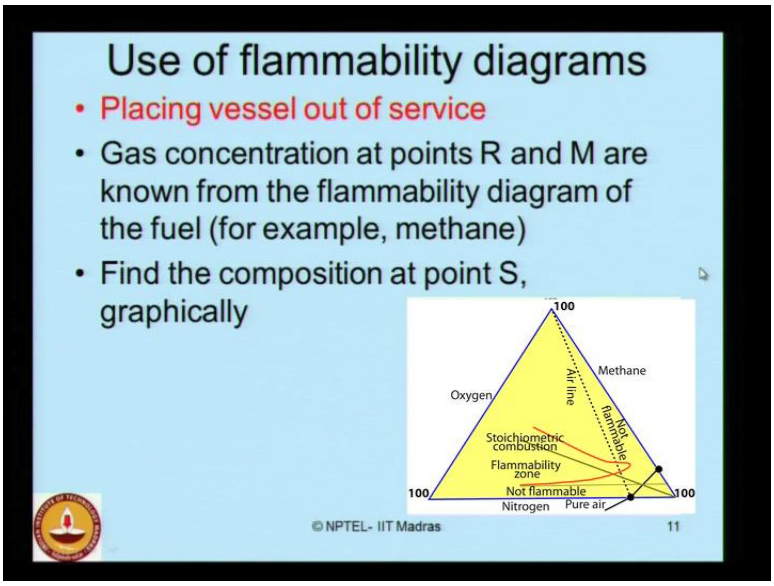

Let us for example, consider placing the vessel out of service. On the right side, what you see here is a typical flammability diagram being plotted for methane as a fuel. As I said, flammability diagram has got three arms, one, two and three. This is what we call as an oxygen arm; this is what we call as a nitrogen arm; this is what we call as a fuel arm. You understand for a specific concentration of pure air at you will be able to plot what we call as an air line which connects the apex of the fuel arm with that of the pure air in the nitrogen arm.

So, the region which is lying here is non-flammable, and the region which is covered here is basically the flammability zone, and anywhere outside the zone are non flammable, for example, this zone as well as, this zone - they are non flammable. Now, a flammability diagram is plotted for a specific fuel which is methane. I am trying to discuss placing vessel out of service with this diagram

Now, look at the points R and M. The gas concentration points at R and M are known for the given flammability diagram of the fuel. In this case, I have taken the example as methane. I hope you will have no doubt in getting the intersection of this point to get the point M and of course, the pure air presence on the nitrogen arm as R. So, the gas concentration points at R and M are known to me in my flammability diagram.

Once this is known graphically you can estimate the composition at point S. Once you estimate the composition at point S, you can use this composition of point S to limit the fire accident.

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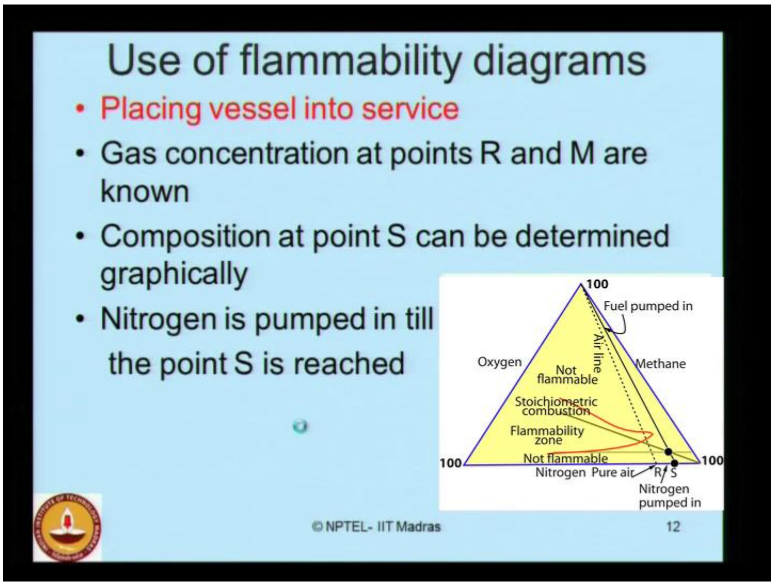

Now, let us see how to use the flammability diagram for placing vessel into service. The moment I know where is my air line and where are my flammable regions. This is my flammable region, this is my non-flammable region, and of course, this also my non-flammable region. Once I know the flammable region, if you have plotted my air line as usual, I will be able to get the point R and M automatically for the specific fuel in the flammability diagram.

Composition at point S can be determined, once I know the composition point S this is the zone or the concentration where nitrogen purging can be done. So, nitrogen is pumped in or we can pump the fuel also here. So, both ways, you can do the purging activity and try to decide at what concentration of LOC, you will be able to place the vessel back into service. So, nitrogen is pumped in till the point S is reached, because this is your concentration currently present. You keep on pumping nitrogen till the point S is reached and therefore, you are actually doing what we call as nitrogen purging.

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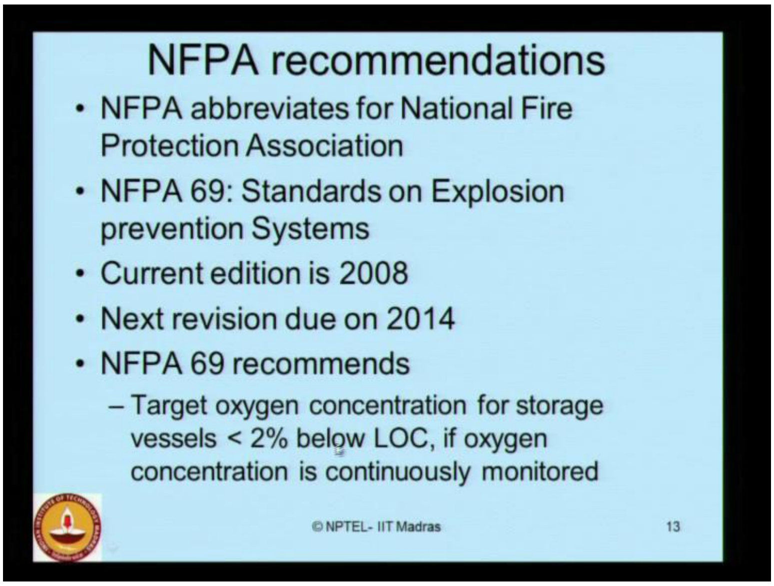

Now, there are some NFPA recommendations by which you can design the safety for fire prevention and prevention against combustion explosion. NFPA abbreviates for National Fire Protection Association - a statutory body of United States. NFPA 69 exclusively discusses the standards on explosion prevention systems; this is a standard prized publication available from NFPA homepage. The current edition of NFPA 69 is revised in the year 2008; the next edition will be on the year 2014.

Let us quickly see, what are the NFPA recommendations for explosion prevention systems. The NFPA 69 recommends a target oxygen concentration for storage vessels. If you are using any container for storing, an explosive chemical then the target oxygen concentration for storage vessel should be less than 2 percent below the limiting oxygen concentration for that fuel. This is applied only when you are continuously monitoring the oxygen concentration in the storage vessel. There are mechanisms by which you can continuously monitor the oxygen concentration in a given storage vessel. If such continuous monitoring happens, then NFPA recommends the target oxygen concentration for storage vessels as lesser than 2 percent below the limiting oxygen concentration of that fuel.

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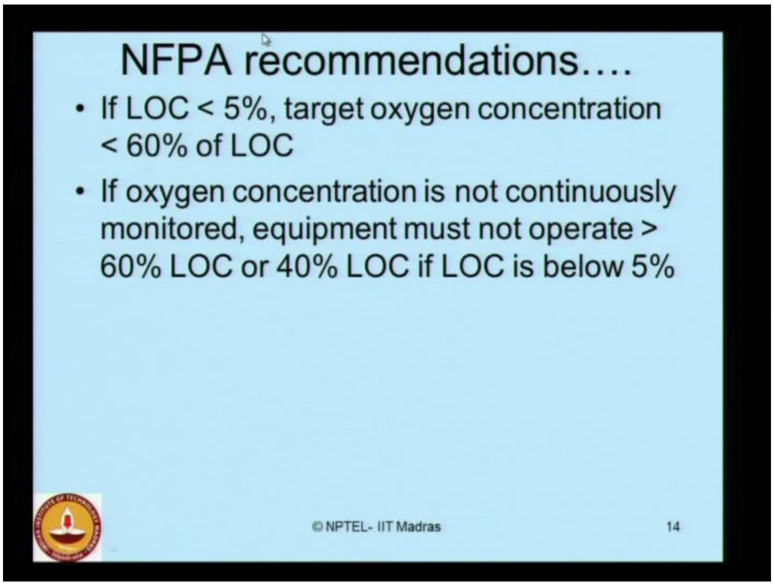

If LOC value is less than 5 percent then the target oxygen concentration should be less than 60 percent of LOC. Please remember, limiting oxygen concentration is different from the target oxygen concentration of the storage vessel. If oxygen concentration by any chance is not continuously monitored in your plant, the equipment then must not operate above 60 percent of LOC or 40 percent of LOC if LOC is below 5 percent. These are NFPA recommendations for avoiding fire accidents or explosions under combustion.

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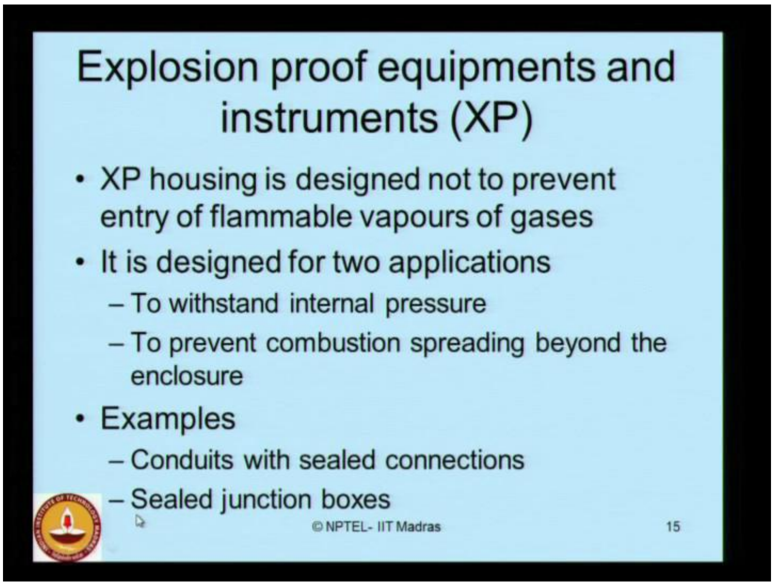

The third method by which we can do fire prevention or control is by designing what we call fire proof equipments and instruments. Generally ladies and gentlemen, in equipments and instruments being used for oil and gas industry in production or storage platforms, you will always have the mark XP written on top of the vessel or the equipment. XP indicates explosion proof. XP housing is basically designed not to prevent the entry of the flammable vapours of the gases. Any explosion proof equipment or instrument does not prevent the entry of flammable vapours of gases. It is designed for two applications namely to withstand the internal pressure being generated during such explosions, to prevent combustion spreading beyond the enclosure.

Ladies and gentlemen, you can also design a container or an area or a specific work space which can also be called as explosion proof. In such cases, we are not preventing that enclosure or protecting the enclosure by entry of flammable gases. We are actually making the enclosure to withstand internal pressure and to prevent the combustion spreading beyond the enclosure, that is what we call as explosion proof design.

There are many examples which we have sited, which you would have known I can give a very quick example to you for your understanding. There can be conduits closed pipes with sealed connections marked as XP. These conduits will maintain internal pressure during extraordinary combustion accidents as well as they will not allow spreading of the combustion beyond the conduit. The second example, what you can see can be a sealed junction boxes being used in electrical circuits. In case of any static electricity short circuiting then these sealed junction boxes can act as an explosion proof equipment.

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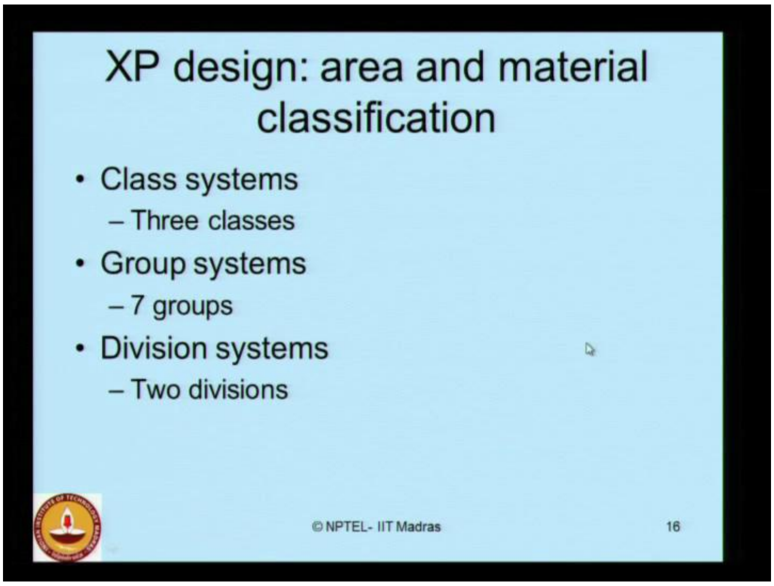

Coming to the explosion proof design, can we design an area using a specific material? The question is can I design an enclosure which is explosion proof? The design is possible, but you have got to basically design the specific area and you have got to use only classified materials in that case. Let us see what are these guidelines? There are three ways by which you can define these systems - one is what we call as a class system; other is what we call as a group system; the third one is what we call as a division system

The class system further has three classifications within itself. The group system has seven groups within itself, and the division system has two divisions within itself. You can always design an explosion proof area and the material is got to be classified depending on any one of these three divisions as class systems, group systems, or division systems.

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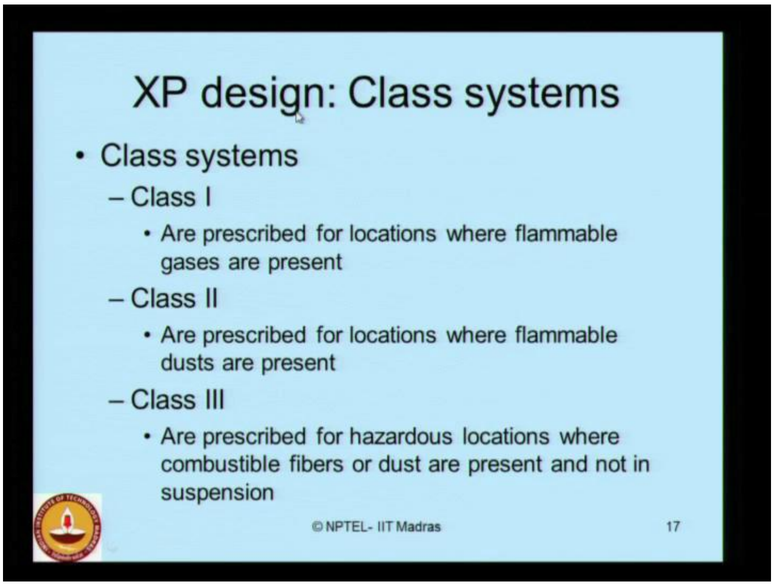

Now, let us talk about the class systems explosion proof design. Class system consists of three classes as I said class I, class II and class III. Class I is applicable to are prescribed for locations where flammable gases are present. You generally advise a class I system of explosion proof design where flammable gases are present. Class II systems are generally prescribed for locations where flammable dusts are present. Class III is prescribed for hazardous locations where combustible fibers or dusts are present, but they not likely in suspension; they are in the contained environment.

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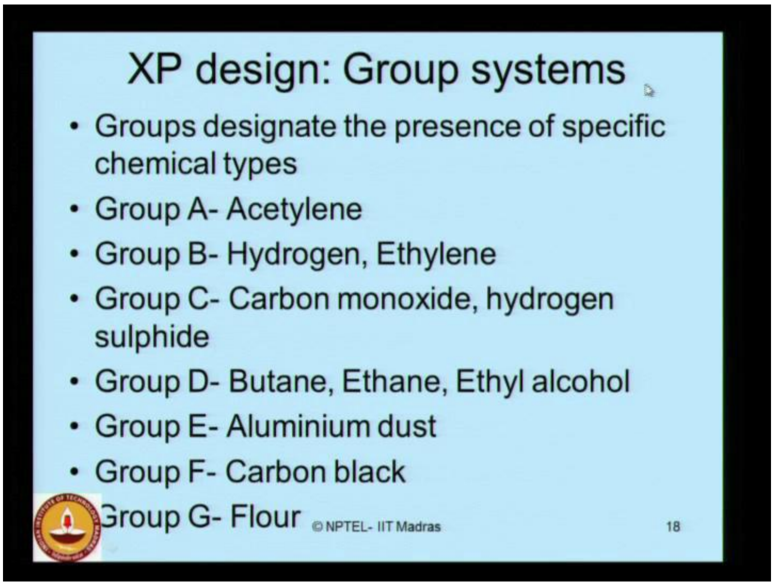

Look at the explosion proof design tips for the group systems, as I said there can be groups that can designate the presence of specific chemical types. For example, group A talks about the presence of acetylene chemical; B talks about the presence of hydrogen ethylene chemical; C talks about carbon dioxide hydrogen sulphide; D group system is for butane, ethane, ethyl alcohol. Group E is meant for aluminium dust. Group F is meant for carbon black. And group G is meant for flour it is nothing, but a fine dust. So, if you look at the group system design as advisable by NFPA depending upon which chemical you are handling accordingly you can select a specific order of the design from group A till group G.

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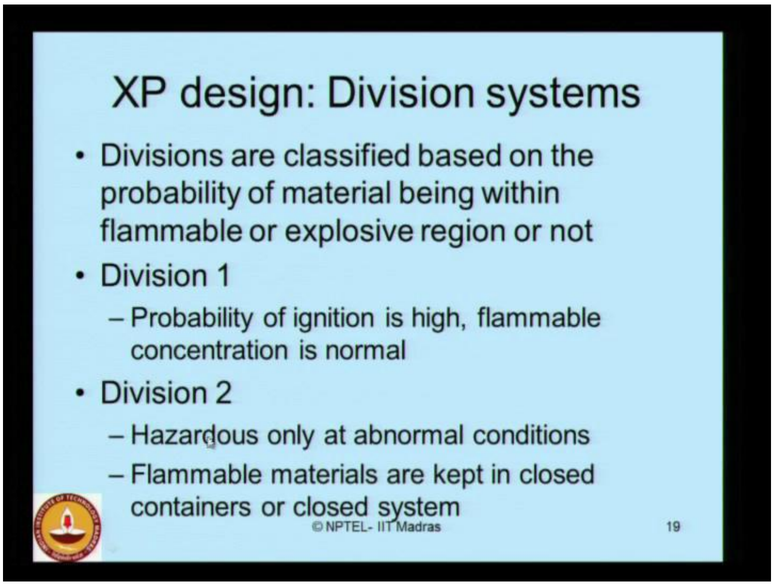

Explosion group design can also be classified based on division systems. Divisions are actually classified on the basis of probability of material being within flammable region or explosive region or not. If you have a flammable material, whether the probability of that material being stocked or stored within the flammable region or an explosive region or not depending upon the probability of the number then you can always classify explosion group design in the division the systems as below.

Division 1 says, the probability of ignition is very high, but the flammable concentration is normal. Division 2-design says, the situation is only hazardous at abnormal conditions under normal operation temperature and pressure the condition is under control. Only at abnormal condition, the situation becomes hazardous. But flammable materials are kept in a closed container or in a close system.

So, ladies and gentlemen, in explosion proof design based on division systems you can easily note that division 2 is having more or less controlled environment compare to division 1. Because in division 1 design or division 1 type of design, the probability of ignition of the material is very high and flammable concentration is of course, said to be normal. Whereas, in division 2-type design the hazardous situation occurs only under abnormal conditions, unexpected. So, it is really an accident scenario where the probability of occurrence of this situation is very rare.

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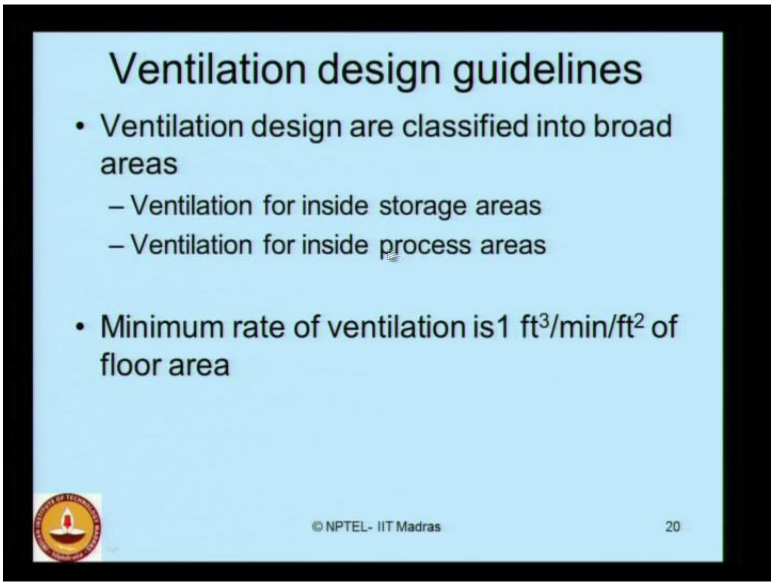

As I said, we can also design explosion proof for fire prevention based on what we call effective ventilation design guidelines. I can also design the ventilation effectively. So that I can avoid accidents, I can control the fire accidents and explosion if at all they occur, if my ventilation design is properly done. The ventilation designs are classified into broad areas. One is ventilation for inside storage areas; other is for ventilation for inside process areas. There are two design guidelines given in the literature; one is for the storage; one is for the process; remember both of them are for inside. Of course, if it is an open ventilation system then there is no question of any guideline, because you get enough type of ventilation, naturally available for an open storage area or an open process systems.

The ventilation guidelines are strictly meant only when these storage and process happens in a contained environment, what we call inside areas. In both the cases, whether it is meant for storage or for process the minimum rate of ventilation is one cubic feet per minute per square feet of the floor area. So, you know what is your floor area in square feet, you can always design what should be your rate of ventilation depending upon what is the volume of your room and for one minute you must at least have one cubic feet for one square feet area of your storage. This is common in both cases of storage and process as well.

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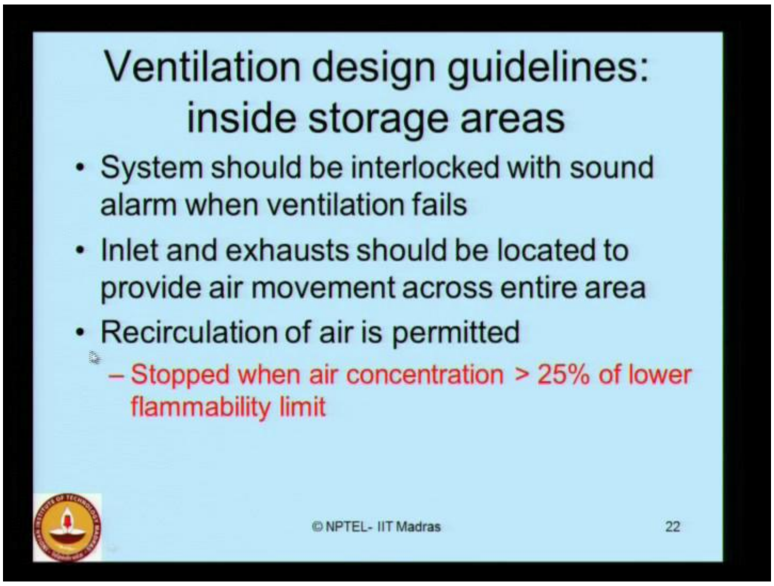

In case of inside storage areas the system should be interlocked with sound alarm when ventilation fails. This is one of the essential design requirement for an inside storage area. Your system should have proper networking of sensors which are interlocked and they raise a sound alarm when the ventilation system actually fails in your storage area. The inlet and exhaust should be located to provide smooth air movement across the entire floor area; this is very important. So, in layman's language people call this as good cross ventilation. So, an inlet and exhaust should be located on the floor such a way that the air movement is smooth and the air moves practically across the entire area of your floor.

The recirculation of air is permitted, for example, you are looking for artificial exhaust system or artificial ventilation system, you can re-circulate the air provided it should be stopped when the air concentration exceeds 25 percent of the lower flammability limit of the fuel for which the flammability diagram is available are being discussed. If your air concentration increases 25 percent of the LFL value of the fuel where you are talking about the storage then recirculation should be not continued.

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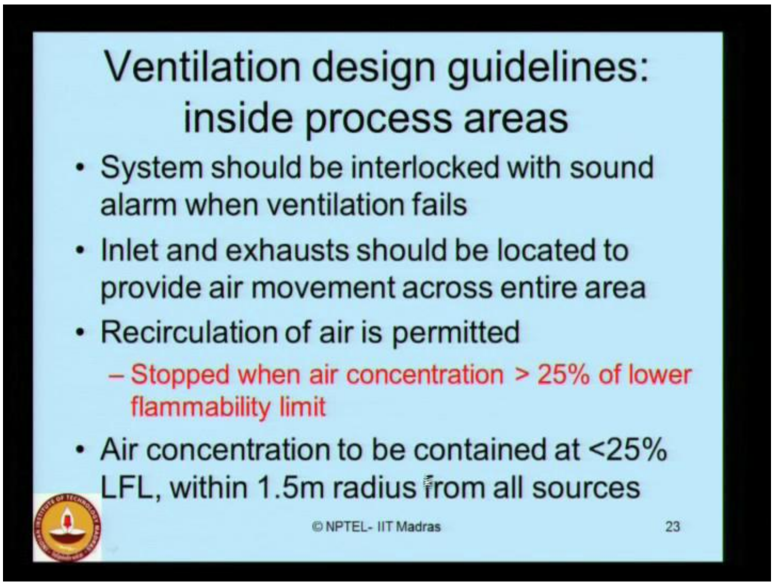

If you look at the ventilation design guidelines for the process areas located inside the plant then system should be again be interlocked with good networking of sensors and these sensors should raise sound alarm when ventilation fails in the system. The inlet and exhaust should be located thoroughly across each other to have a very good air movement across the entire area; it is as same as the storage facilities as well. The recirculation of air is permitted and it is stopped when the air concentration exceeds 25 percent of the lower flammability limit. In addition to that the air concentration should be contained below 25 percent of LFL. This is a very important requirement of the design guideline for the process areas which is different from that of the storage areas.

The air concentration should be contained to be lower than 25 percent of the lower flammability limit of the fuel. Further the air concentration should lie within one point five meter radius from all possible source of ignition. So, it is what we call as contained environment. In case any such process in the area fails from ventilation guidelines then control of fire or combustion reaction can be possible within a short reaction of span of time. So, two conditions exclusively are required for inside process areas, air concentration should be lower than 25 percent of lower flammability limit of the fuel, and the air concentration should lie within 1.5 meter radius from all possible sources of ignition.

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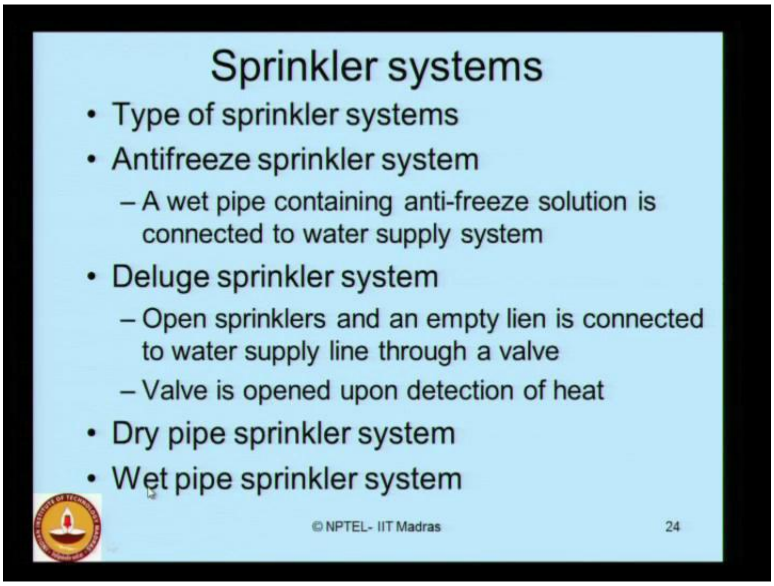

Lastly, when we talk about the effective control of fire accidents and prevention, we can also design what we call as sprinkler systems. Ladies and gentlemen, you must have seen a very common sprinkler system being used for gardening in large areas. Nowadays, under HVAC regulations that is heating ventilation and air conditioning regulations for controlled space in any multi-storey building; sprinkler systems are mandatory for fire protection devices.

You must have seen in your buildings lot of pipe lines, water lines being painted as a red in color, and there are many sprinklers located along the periphery of these pipelines in the entire room or in an entire cabin where you have been working in your offices. Sprinkler systems are essentially used for controlling fire, in case a fire occurs. There are different types of sprinkler systems being used. One is what we call anti freeze sprinkler system. In this anti-freeze sprinkler system design - a wet pipe system that containing anti freeze solution is actually connected to your water supply system. In the deluge sprinkler systems - the open sprinklers and an empty line is connected to water supply line through a valve. This valve is opened when heat is detected by censors. In a dry pipe, sprinkler system and a wet pipe sprinkler system are two different sprinkler systems other than what we have seen here.

In a dry pipe sprinkler system, the pipe network is being connected to overhead tank supply and the valves will open automatically upon detection of heat using sensors. In the wet pipe sprinkler system, the pipe will always be loaded with water which is supplied from the overhead tank on the sprinkler system network.

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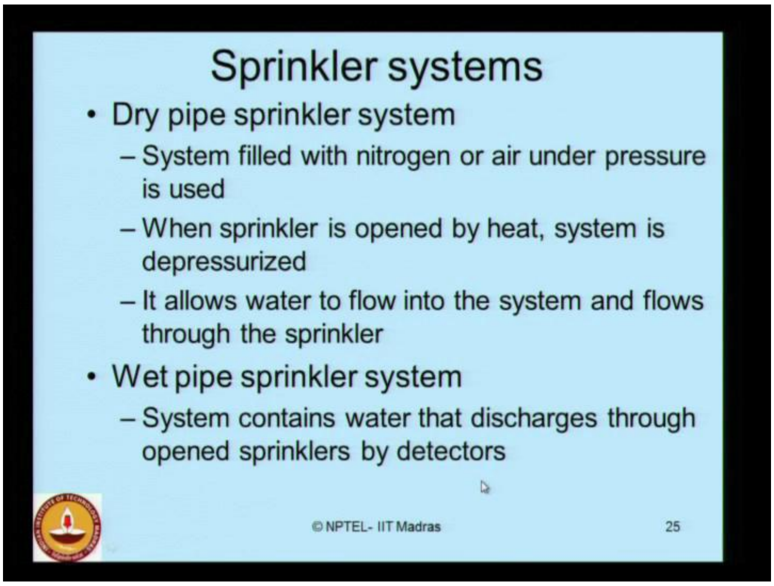

In the dry pipe sprinkler system, the system is filled with nitrogen or air under pressure when the sprinkler is opened by heat system is depressurized, it now allows water to flow into the system and flows through the sprinklers attached to the system. You may wonder that why the nitrogen should be filled up in the dry pipe. If the dry pipe is left hollow or free for a longer duration, then there can be what we call as an air locking in the pipe system which may not allow water to enter. Incase, when the sprinklers are open. Therefore, the dry pipe system should have nitrogen or air filled in the system under pressure, when the sprinklers get opened by the heat detectors, the system is automatically depressurized which will allow water to flow from the overhead tank into the system. And this water contain now we will flow through the sprinklers and control fire.

In case of wet pipes sprinkler system, as I discussed earlier the system contains water that discharges through open sprinklers which are opened otherwise by heat or fire detectors. Ladies and gentlemen, these detectors being used in the sprinkler systems are nothing, but head detectors, whenever there is in case of fire the temperature inside the room rises beyond a specific value for which these detectors are programmed. Once the temperature reaches the value, the sensors will open the sprinkler system automatically and the water will start flowing from the system to the discharged area. This can be used as effective design sprinkler systems for controlling fire accidents as one of the designed methodologies.

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When you look at the guideline of sprinkler system design as given by NFPA, the nominal discharge rate of a 12 millimeter diameter orifice spray nozzle is given below. The orifice should spray 18, 25, 34, 50 or 58 gallons per minute with a pressure of 10, 20, 35, 75, 100 psi respectively depending upon what capacity is your tank supply. This discharge rate is being specified by NFPA for a 12 millimeter diameter orifice spray nozzle, which is being used as a sprinkler system in your design.

Thank you.