Health, Safety and Environmental Management in Petroleum and offshore Engineering

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Module No. # 03

Lecture No. # 10

Fire and Explosion preventive measures

Good morning, ladies and gentlemen. In the last lecture, we discussed about the fire and explosion models, we explained you how to draw flammability diagrams. We have taken some example and demonstrated how to draw flammability diagram. In today's lecture, we will divide this into two parts. In the first part of the lecture, we will speak about fire and explosion preventive measures. In the second part of the lecture, we will talk about probabilistic risk analysis, which is PRA.

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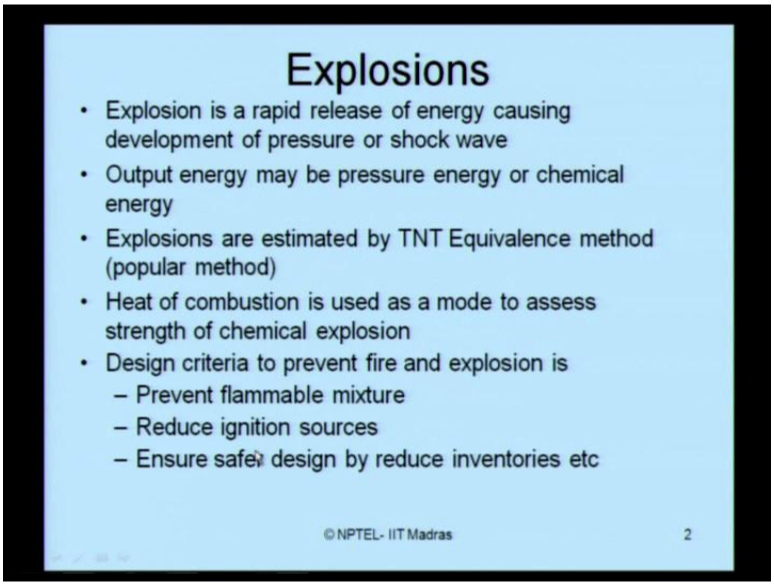

When we talk about explosion preventions, let us first try to understand what do we mean by the explosion. We already discussed this in the last presentation, just for a summary. Explosion is a rapid release of energy causing development of pressure or a shock wave. The output energy, what you get from an explosion may be a pressure energy or a chemical energy. The explosions are generally estimated by what we call as TNT equivalence method. This is considered as one of the popular method in the common practice.

Heat of combustion is used as a mode to assess the strength of chemical explosion. The design criteria to prevent fire and explosion can be the following. Prevent the flammable mixture in your plant or reduce ignition sources present in the system or ensure safer design by reducing inventories in the plant etcetera. These are some of the basic design criteria which you can employ to prevent fire and explosion.

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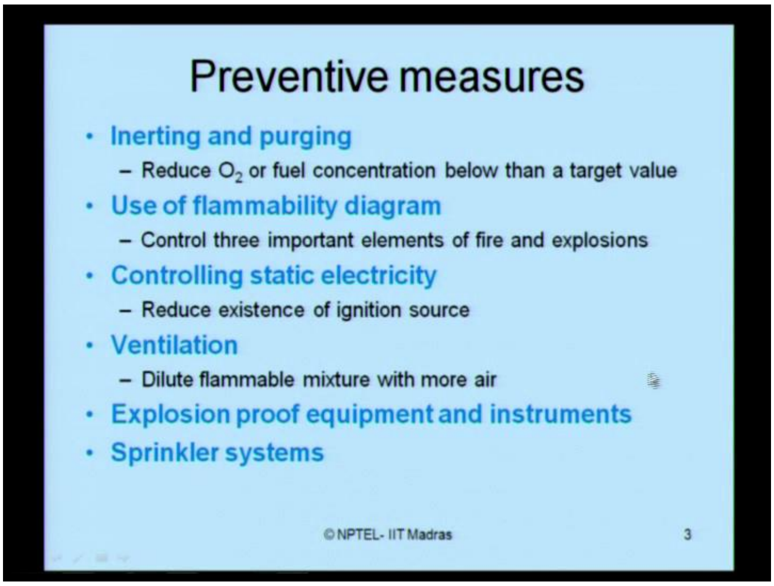

We also looked at some of the preventive measures which we said inerting and purging. This is a process by which a reduced oxygen content or the fuel concentration below a target value. We also understand how we can use the flammability diagram, we will discuss that in detail now. From the flammability diagram, you can easily control three important elements of fire and explosion. The other preventive measure is what we call as controlling static electricity; that is to reduce existence of ignition source itself. The other measure is ventilation. Dilute the flammable mixture with more air, because if you provide more ventilation; obviously, the flammable mixture which is causing explosion of fire will get diluted due to high concentration of air present in the system.

Ladies and gentlemen, you can recollect that in the last lecture number-9 on module-3, we discussed in detail different methods of inerting and purging. In the current lecture, we discuss about usage of flammability diagram as a preventive measure for fire and explosion. We will also discuss, about the controlling phenomenon of a static electricity and how to have better ventilation. Of course one can use what we call as explosion proof equipments and instruments. What are these kinds of instruments we will discuss them in detail in today's lecture. And of course, we will also discuss about different kind of sprinkler systems that can also be employed for as a preventive measure for reducing or eliminating fire and explosion in offshore and petroleum industries.

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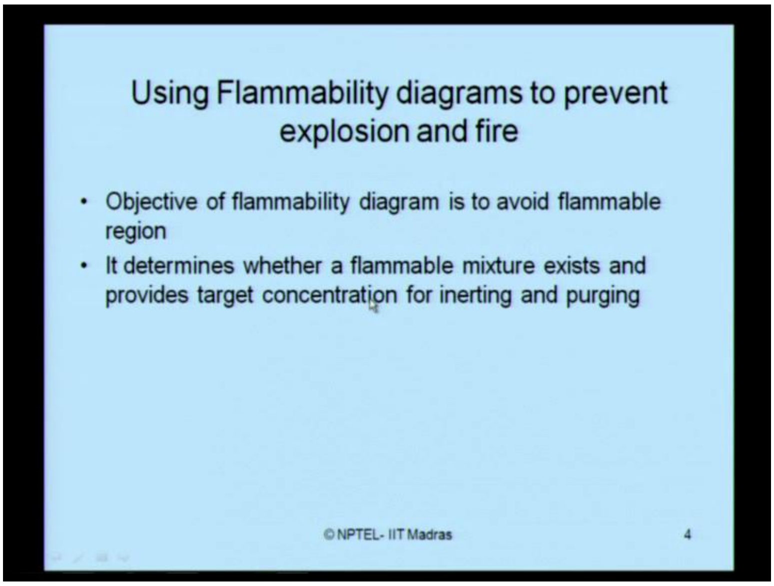

How one can use a flammability diagram to prevent explosion and fire? Before we answer this question, let us try to recollect what is a flammability diagram, how a diagram is drawn, for a given example how you will plot a flammability diagram. I am not going to repeat this exercise. Once again in this lecture, those who have difficulties, I may request them to get back to my previous module to understand how to draw flammability diagrams with examples.

Let us understand that all of us know how to draw at least the flammability diagram. What we understand from a flammability diagram is primarily the area, which is flammable and the area which is not flammable. Now, let us use this diagram to understand prevention of explosion and fire. The objective of a flammability diagram is actually to avoid flammable region. It means this diagram will tell me very clearly what are the flammable regions for the given mixture.

Once I know that from this diagram, I can understand how to avoid the flammable region. It determines whether a flammable mixture exists and provides target concentration for inerting and purging. If a mixture is known from a flammability diagram, you will know whether that mixture becomes flammable or not for a given operating temperature and pressure. If that exists then the flammability diagram will tell me the target concentration for inerting and purging.

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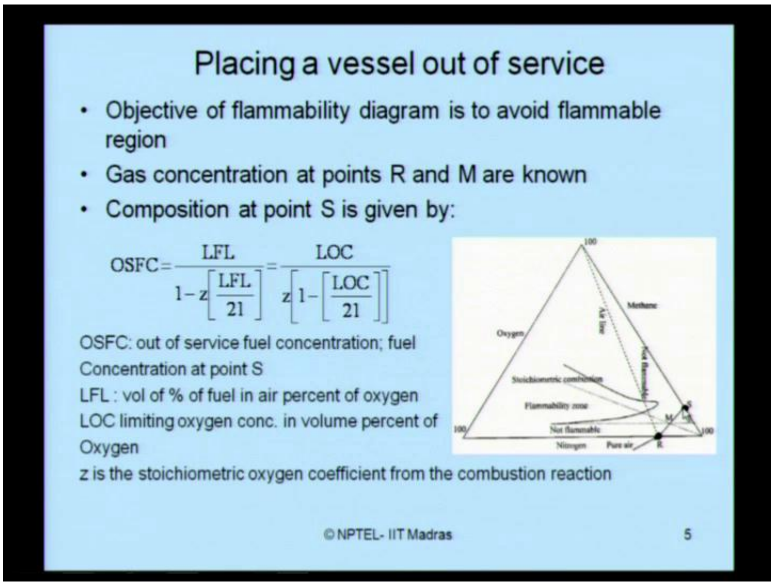

Let us look at this calculation. Let us consider that i am placing a vessel out of service that is called out of service. The objective is to avoid flammable region. Let us say this is my flammability diagram it has got three arms of a triangle. Methane which is the fuel in this case as an example oxygen and nitrogen. So, there is a standard way of marking every arm zero to hundred zero to hundred anti clockwise which we already know how to draw this diagram. The air line is the line which is joined in the apex to the nitrogen concentration of our seventy nine percent in pure air. So, i draw this line and then i draw this stoichiometric line, for stoichiometric condition given for a specific mixture from the stoichiometric concentration reaction

I get this line then I mark the LFL and UFL of the mixture on the oxygen arm then I can keep on drawing the nose of this curve and this becomes my flammable region which is already known to me.

Now, the gas concentration at the points r that is on the nitrogen arm and at the point m which is the nose or the intersection of the stoichiometric line is known to me, where the gas concentration are known to me. Once I know that, then the composition of the point s is given by a simple expression LFL by 1 minus z LFL by 21 or LOC by z into 1 minus LOC by 21.

Ladies and gentlemen, you can easily recollect that this 21 is nothing but 89 percent of nitrogen which gives me the air line which I show here. So, this point is nothing but 79 percent or 80 percent of nitrogen or 21 percent of oxygen. So, I get this line and that is what I call as vessel out of service concentration. So, OSFC is out of service fuel concentration.

The fuel concentration point is given at the point s, because this is my fuel arm in this case the fuel is taken as methane gas. LFL is volume of percentage of fuel in air percent of oxygen. LOC is what we understand as limiting oxygen concentration expressed in volume percentage of oxygen. And z is the stoichiometric oxygen coefficient for the given combustion reaction. So, once I know all these values, I substitute either in this equation or in this equation accordingly to get my vessel out of service fuel concentration. So, I can easily locate the point s and see whether the point s is lying or going to be in the flammable region or not.

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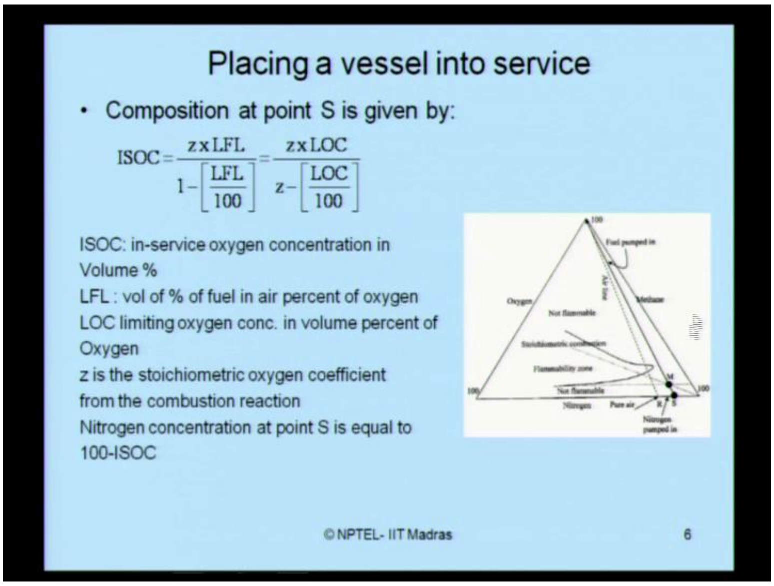

Suppose you want to place the vessel into service back, because if you want to remove the vessel from service then it should be lying in the non flammable region. Similarly, if you want to place the vessel in service, you should place it only in a non flammable region.

Now, the composition at the point s on the nitrogen arm will be given by a simple expression which is based upon LFL or as usual LOC where ISOC is what we call as in service oxygen concentration in volume percentage. LFL is volume of percentage of fuel in air percentage of oxygen and LOC is what we called as limiting oxygen concentration expressed in volume percent of oxygen. So, based on this equation or on this equation I can easily estimate the in service oxygen concentration in volume percentage for a given mixture. When I want to place the vessel in service back, in this equation z is the stoichiometric oxygen coefficient which you get from the reaction of the mixture with oxygen - that is a chemical combustion equation.

The nitrogen concentration at point S is then equal to 100 of ISOC. So, if you have the S value then the nitrogen concentration is nothing but 100 minus what you get from this equation will give me the nitrogen concentration of S on the nitrogen arm. I get ISOC, then 100 minus ISOC will give me or enable me to fix the point S in the flammability diagram.

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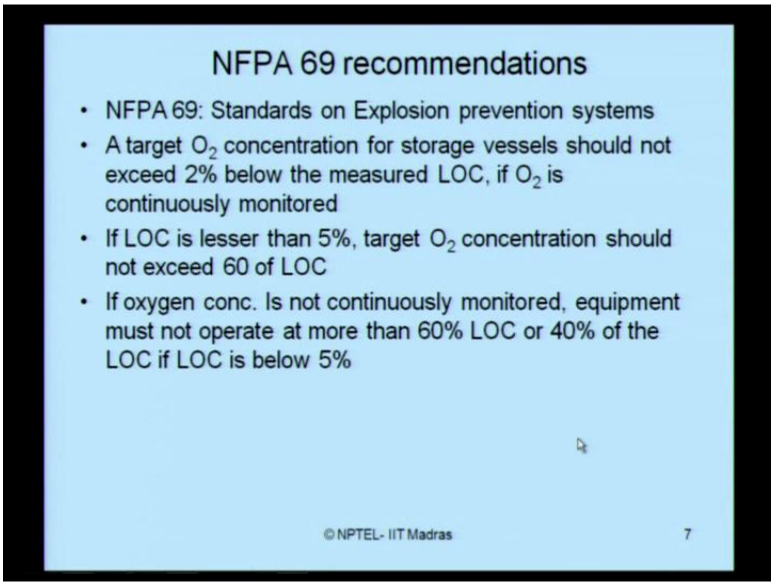

If you look at NFPA 69 recommendations, which is meant for standards on explosion preventive systems; in NFPA 69 recommends that a target oxygen concentration for a storage vessel should not exceed 2 percent below the measured LOC, if oxygen is continuously monitored. If oxygen is not continuously monitored then LOC, if LOC lesser than 5 percent then the target oxygen concentration should not exceed 60 of LOC. If the oxygen concentration is not continuously monitored, then the equipment must not operate at more than any cost 60 percent of LOC or forty percent of LOC if LOC is below 5 percent.

Ladies and gentlemen, NFPA simply recommends a target oxygen concentration based upon what is your LOC. If your LOC is below 2 percent and you are continuously monitoring oxygen, then it should not exceed 60 percent of LOC. If you are not continuously monitoring the oxygen concentration then, if your LOC is below 5 percent then it should not exceed maximum 40 percent of LOC and so on so forth.

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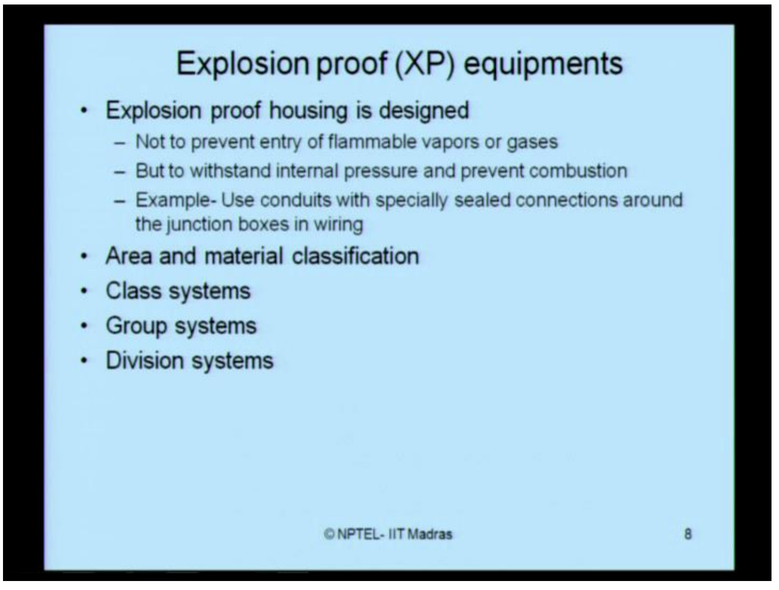

When we look at the prevention measures by using what we called as explosion proof equipments. The explosion proof housing can be designed, not to prevent entry of flammable vapors or gases. You can also design an explosion proof housing to withstand internal pressure and to prevent combustion. For example, use conduits with specially sealed connections around the junction boxes in wiring of the houses and that wiring system or that house can be also accorded as an explosion proof housing. So, one can design an explosion proof housing that is one format of preventing fire and explosion. When we look at the area and material classification, we can also consider the class systems for explosion proof design. We can also consider group systems for explosion proof design. We can also consider, what we all as a division system for x p designs.

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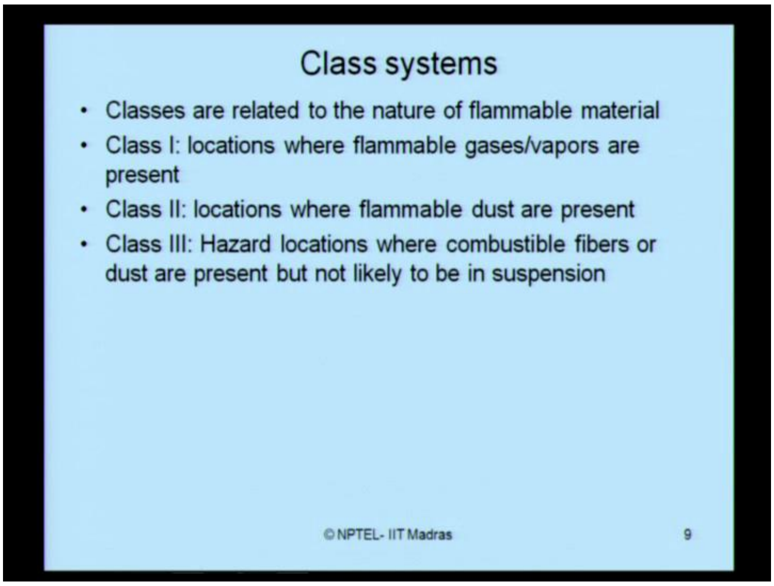

Then next question follows is, what do we understand by class systems? Classes are actually related to the nature of the flammable material. You have class 1, class 2, class 3. Class 1 talks about locations where flammable gases or vapors are present. Class 2 talks about the locations where flammable dust are present. Class 3 talks about the hazardous locations where combustible fibers or dust are present, but they are not likely in suspension.

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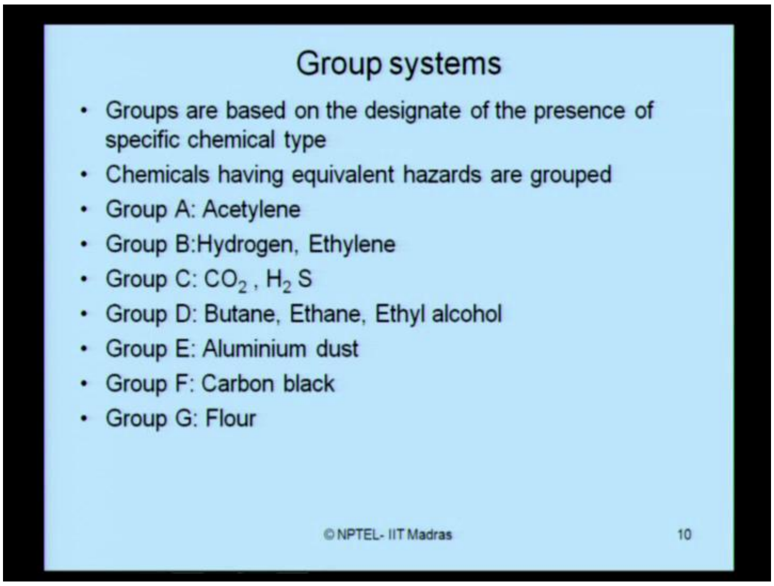

When you look at the group systems then the question comes what we understand by group systems. Now, grouping is actually done on the designate of the presence of specific chemical type. Based on this presence of this specific chemical type you group them. Chemicals having equivalent hazards are actually grouped under one heading. Group A, for example, can be acetylene. Group B can be hydrogen ethylene. Group C can be carbon dioxide hydrogen sulphite. Group D can be butane ethane ethyl alcohol. Group E can be aluminium dust. Group F can be a carbon black. Group G can be a flour which is fine dust and so on so forth.

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You can also design what we called as division systems for creating explosion proof equipments. What do we understand by division systems? The regions are actually categorized in the given system in relationship with a probability of material being within the flammable region or the explosive region. On the other hand, if you have got any specific kind of material which is being used for that particular inventory or for the plant, let us try to see what is that probability of that material being located within the flammable region of the plant. Then, accordingly you categorize the region based on higher probability of material to be within the flammable region or lower probability of the material to lie within the flammable region.

So, you divide the whole system into different regions characterizing them based on what is the probability of material being within the flammable region or the explosive region. So, in that division system we can say division 1, the probability of ignition is very high and the flammable concentration are generally present. You can then say my division 2, has hazardous only at abnormal conditions. The probability of material such a way of being within flammable region exists, but it becomes hazardous only at abnormal conditions. Flammable materials are normally contained in a closed container. So, what we called as a containment system - we call that region as division 2.

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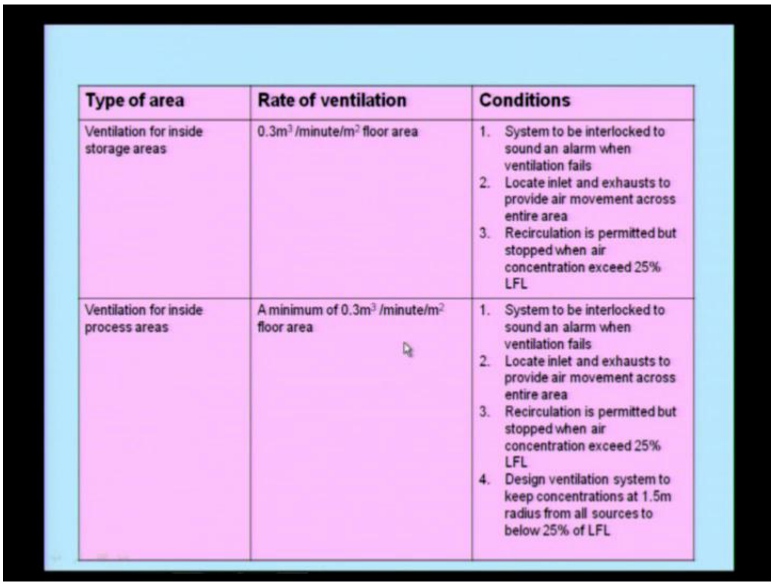

Type of area	Rate of ventilation	Conditions
Ventilation for inside storage areas	$0.3m^3$ /minute/m^2 floor area	1. System to be interlocked to sound an alarm when ventilation fails 2. Locate inlet and exhausts to provide air movement across entire area 3. Recirculation is permitted but stopped when air concentration exceed 25% LFL
Ventilation for inside process areas	A minimum of $0.3m^3$ /minute/m^2 floor area	1. System to be interlocked to sound an alarm when ventilation fails 2. Locate inlet and exhausts to provide air movement across entire area 3. Recirculation is permitted but stopped when air concentration exceed 25% LFL 4. Design ventilation system to keep concentrations at 1.5m radius from all sources to below 25% of LFL

Thirdly, if you look at the alternative design for explosion proof equipments; one suggestion what we can give is that improve ventilation in the plant. You can dilute the flammable mixture by increasing the air concentration in the fuel. In that, let us see this simple table to understand, how can I design a good ventilation system. For example, if you have a type of area where, the ventilation is done for inside storage areas. You have a plant which is enclosed on all the four sides; you need ventilation for the inside storage area, then you must provide the minimum rate of ventilation as 0.3 cubic meter of air to come in per minute for every square meter of the floor area. For every square meter of the floor area of inside the storage area, you must permit minimum of 0.3 cubic meter of air to enter per minute - that is what the rate of ventilation which is recommended by NFPA to consider or to call that as explosion proof area.

Now, the conditions are system to be interlocked with a sound alarm, when the ventilation fails. When this much amount of ventilation is not made available because of some unknown reasons, then there should be an alarm system which is automatically activated when the ventilation goes below this specimen value - that is a condition to be provided in such ventilations. Locate the inlet and exhaust to provide air movement across the entire area. So, you are allowing an inlet and exhaust system to improve the rate of ventilation inside the storage area. That inlet and exhaust should be provided in such a way that the flow of air is across the entire area that you have to ensure. Do not try to keep the inlet and exhaust at one corner of the ventilation area then even though you provide the rate of ventilation to be of satisfactory requirement; still we cannot accept that as per NFPA standards as explosion proof ventilation.

Subsequently, you must also permit recirculation, when the ventilation goes below, but of course, it is stopped when the air concentration exceeds 25 percent of low air flammability limit. Suppose if you are looking for ventilation guidelines inside the process area, ladies and gentlemen this requirement is for inside the storage area. Now I am looking for the ventilation guidelines inside the process area the minimum of 0.3 cubic meter per minute per square meter is again recommended for the process area.

You may wonder why the guideline for ventilation for storage area and process area is almost similar. It is because inventory kept in the storage area can also be highly probable for explosion or fire accidents. Or the chemical process can also be highly flammable, therefore looking into the fire and explosion possibilities whether it is a storage area or a process area NFPA looks this in a global view that the rate of ventilation suggested for both the segments are appropriately equal.

However, the conditions what we got to satisfy to make that area as explosion proof ventilation if it is inside storage these three points have to satisfied. If it is inside the process, in addition to these three points as I showed here there is an extra condition which you have to satisfy - if it is a process area, that condition is design a proper ventilation system to keep the concentration at 1.5 meter radius from all sources to below 25 percent of LFL. So, that is the additional design ventilation system requirement to make the ventilation explosion proof if it is a process area.

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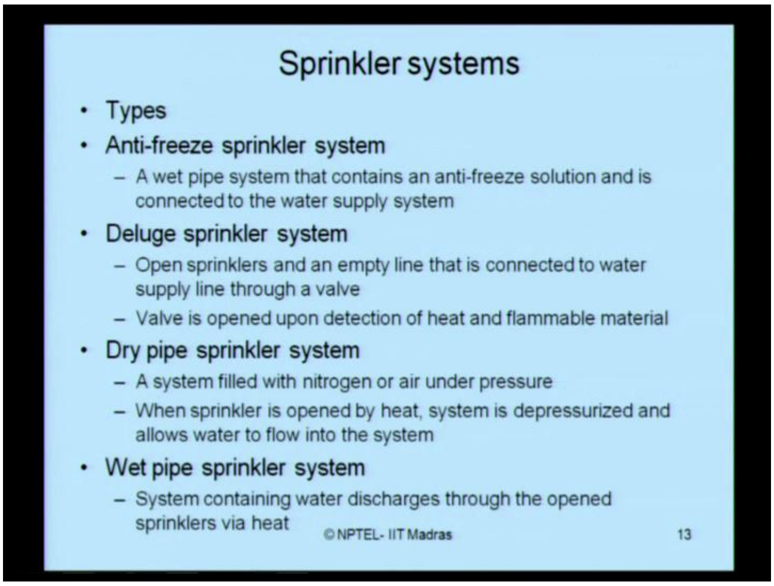

Now, let us discuss about what we call as sprinkler systems. This is again under the category of one of the intelligent ways of designing explosion proof process plant. What do we understand by a sprinkler system, what are different types and so on; we will discuss that now very briefly. There are different types of sprinkler systems that exist. One is what we call anti freeze sprinkler system. A wet pipe system that contains an anti freeze solution is being circulated and that is connected to the water supply system. This anti freeze sprinkler system is very useful in case of countries, which has got a very dropping temperature especially during winter. Because even though the sprinkler system can have a wet pipe system, but during winter because of climatic conditions the chemical or the liquid inside the wet pipe system may get frozen, and therefore the sprinkler system may not work. So, one such type of sprinkler system which is strongly recommended for cold climate countries is an anti freeze sprinkler system. So, you basically circulate what we called as an anti freeze solution through a wet pipe system which is then used subsequently as a sprinkler system.

The next sprinkler system, which is very common is what we call a deluge. A deluge has open sprinklers and an empty line that is connected to the water supply line through a valve. You have an open sprinkler system network connected to an empty line which is subsequently connected to the water supply line through a valve. Now, this valve is opened automatically upon detection of heat and flammable material for example, you have a sprinkler system network which is connected to an empty line and that line is connected to a water supply line maybe from a tank maybe from a sum or maybe directly to a water supply line. Then in that case, that valve should automatically be opened when the sprinkler detects heat or a flammable material in case of any emergency - that kind of system is what we call as deluge.

The third type of sprinkler system which is also common is what we called as dry pipe sprinkler system. This has a system fitted with nitrogen or air under pressure. So, there is no wetness or there is no water or there is no anti freeze liquid which is kept inside this system that is why it is called dry pipe. The system actually has nitrogen or air under pressure. When the sprinklers are opened by heat or by I should say excessive heat then the system is automatically depressurized, and therefore, it allows water to flow into the system. Because initially the system is filled with nitrogen gas under high pressure, when the sprinkler is opened by heat or senses heat which is excessive in temperature or senses of flame through a flame detector, then the system is completely suddenly depressurized; and now the system will allow water to flow into the place where extinction has to take place.

The forth type of system is what we called as wet pipe sprinkler system. The system contains water which discharges through openings of sprinklers via heat. The sprinklers get opened when the temperature reaches a threshold value, when the sprinklers open water discharges through the sprinkler and controls the fire or extincts the fire. So, sprinkler systems has basically four types anti freeze recommended for cold countries; deluge where you connect an empty line to an water supply line through a valve which is operated automatically on detection of heat or flammable material.

Then you also have dry pipe system where the system is under pressure, when the sprinklers senses heat the system is depressurized and water is allowed to flow through the system. Or we have a simple wet pipes sprinkler system, where the system contains water which is discharged through the sprinklers when the sprinklers get opened because of heat or flammable detection.

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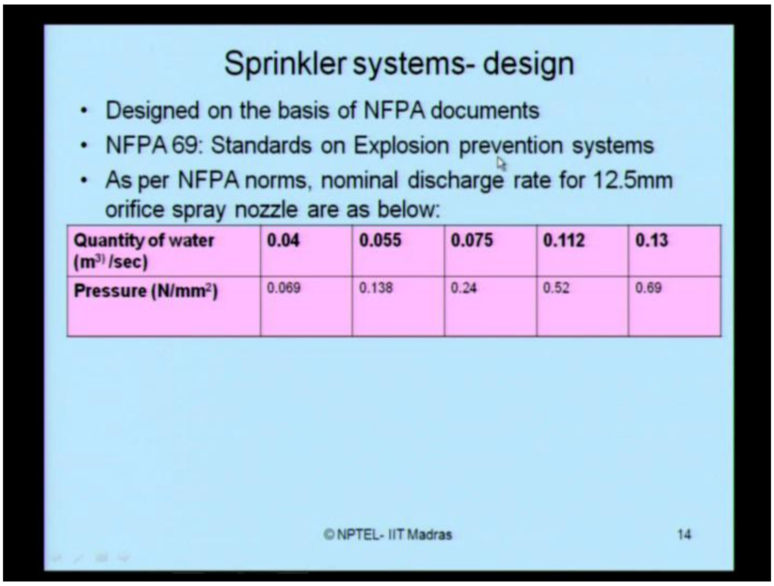

If you look at the design of sprinkler systems then, one much understand how much quantity of water is required at what operating pressure, because it is very essential to design the survival tank or the reservoir which will supply water to the sprinkler system on demand. So, how much quantity of water is required at what pressure it must operate is given as an NFPA guideline. So, NFPA 69 basically tells you what is the minimum quantity of water which should be available on sprinkler systems at what pressure, for example, if the quantity of water is about 0.04 meter cube per second which I call as cumac in my discussion then it must operate at a pressure of 0.069 newton per millimeter square. If you have are having large quantity of water equivalent of about 0.13 cumacs then you must operate this at a pressure of about 0.69 which is ten times of this.

So, ladies and gentlemen, sprinkler system design is readily available in a literature. NFPA specifies the minimum quantity of water corresponding to a specific pressure of operation.

So, you have got to design what is that quantity of water you require and what is the type of system you want to design, which is can be used as an preventive measure for explosion or fire. So, with this we conclude the model discussions on the lecture on fire and explosion models. I am going to talk about the probabilistic risk analysis models subsequently in the next slide. Before we conclude, let us try to get a clue that the normal discharge rate for a 12.5 mm of orifice spray nozzle is what we see here - this is the discharge rate as recommended by NFPA.

Thank you.