Chemical Process Safety

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Lecture 24 - Explosion & Its Classification – 2

So welcome to this module of Fire and Explosion. In the previous module we have studied about the fire and explosion with different modes of heat transfer, heat generated and the fire.

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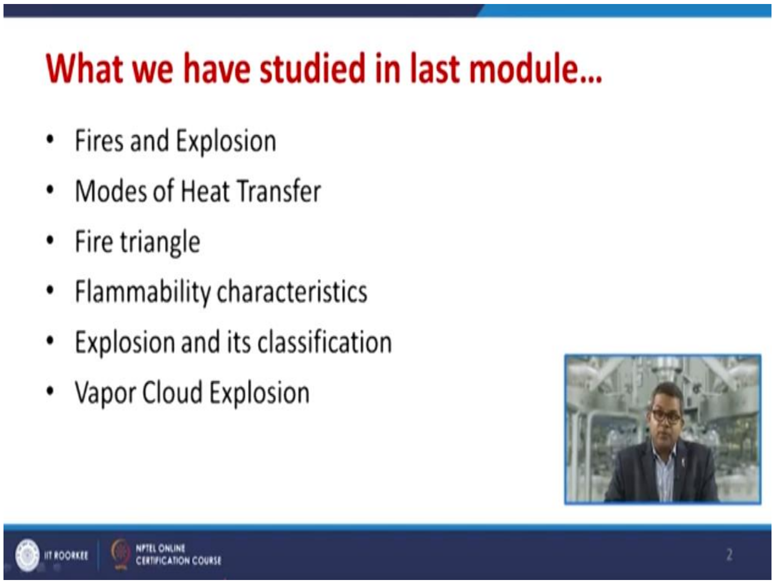

Discussed about the fire triangle, we have discussed about that flammability characteristics, there are different parameters involved in the fire explosion. We have classified the various aspects of explosion, we have discussed and in the previous module we have taken 3 special cases, vapor cloud explosion, BLEVE and dust explosion. So we have completed the discussion about the vapor cloud explosion, however the case studies will be discussed in the subsequent modules. In this particular module we will discuss about the BLEVE, the dust explosion.

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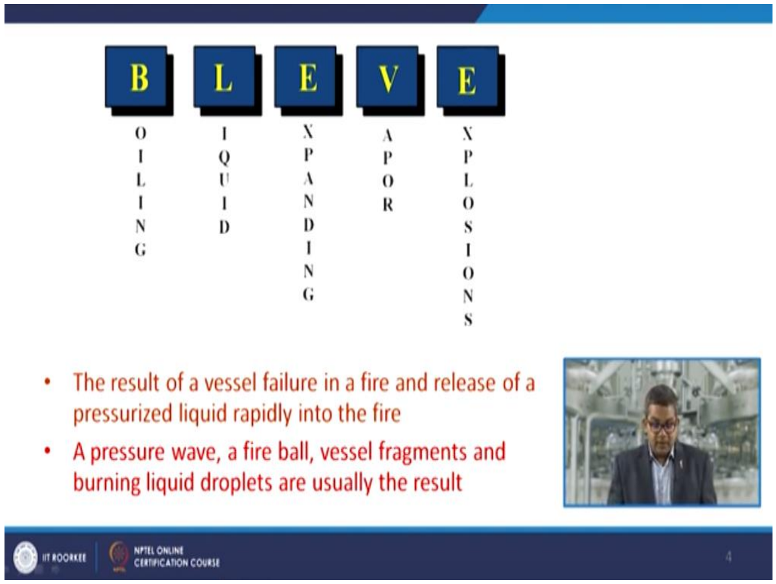

Now BLEVE, the boiling liquid expanding vapor explosion, this is extremely dangerous and destructive explosion. Now the result of vessel failure in a fire releases a pressurized liquid rapidly into fire, now a pressure wave is being generated, a fire ball is being created and the vessel fragments and burning liquid droplets are usually formed in terms of a result.

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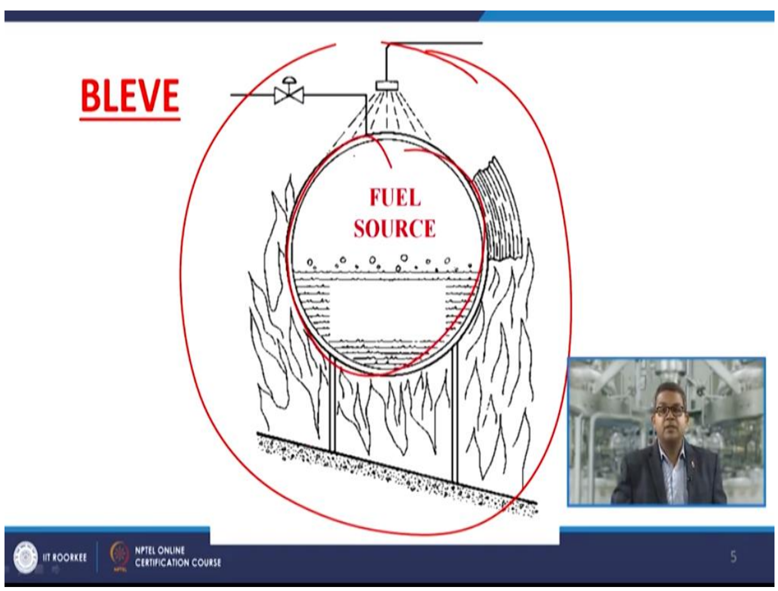

Now this is the typical figure of BLEVE, here this the fuel source and it is surrounded this entire vessel is being heated by some other sources.

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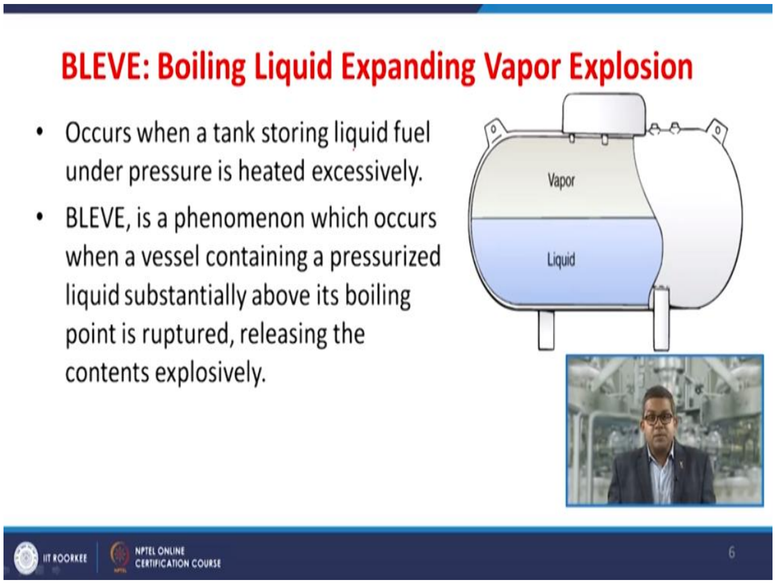

So this occurs when a tank storing liquid fuel under pressure is heated excessively, maybe inherent or maybe some other sources or maybe some external sources or maybe because of the heat being transmitted through various modes of heat transfer. Now BLEVE is a phenomenon which occurs when a vessel containing a pressurized liquid substantially above its boiling point is ruptured releasing the contents explosively. Now remember here the liquid which is inside the pressurized vessel is above its boiling point and moreover the vessel is pressurized.

So by any means if it ruptures there is not only a tendency of releasing the pressure, excessive pressure and moreover since the temperature is so high, so there in a fraction of seconds or in a fraction of time there may be a chance that vapors may generate and it may come into contact with the atmospheric air and if the sufficient supply of oxygen is there or a sufficient supply of source of ignition is there or if the liquid which is inside is sufficiently at high temperature, so it may catch the auto-ignition probability. So let us summarize the incidence of a BLEVE or a sequence and there are different sequences in the BLEVE.

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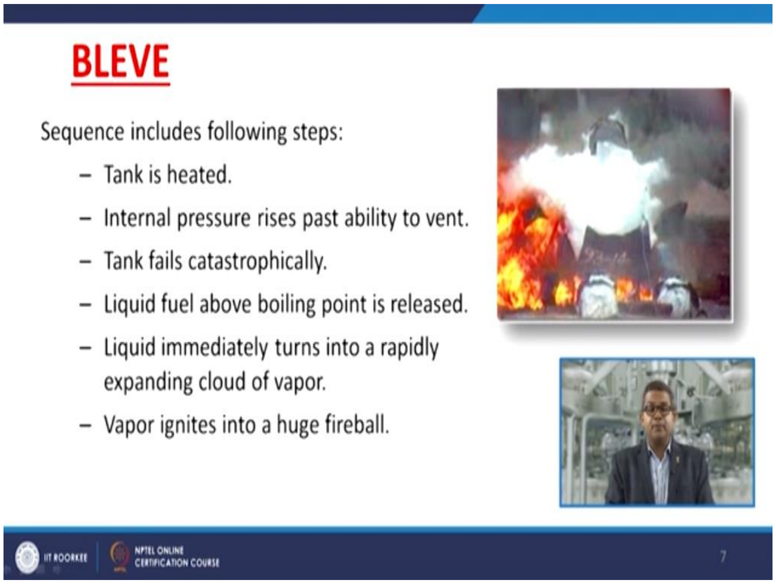

Once it is the tank is heated, now the internal pressure because of the heat rises past ability to vent. Now tank fails catastrophically, the safety devices or it ruptures in any way and a liquid fuel above boiling point is released to the atmosphere, liquid immediately turns into the rapidly expanding cloud of vapors and vapor ignites into the huge fireball, so we can imagine that how destructive it is.

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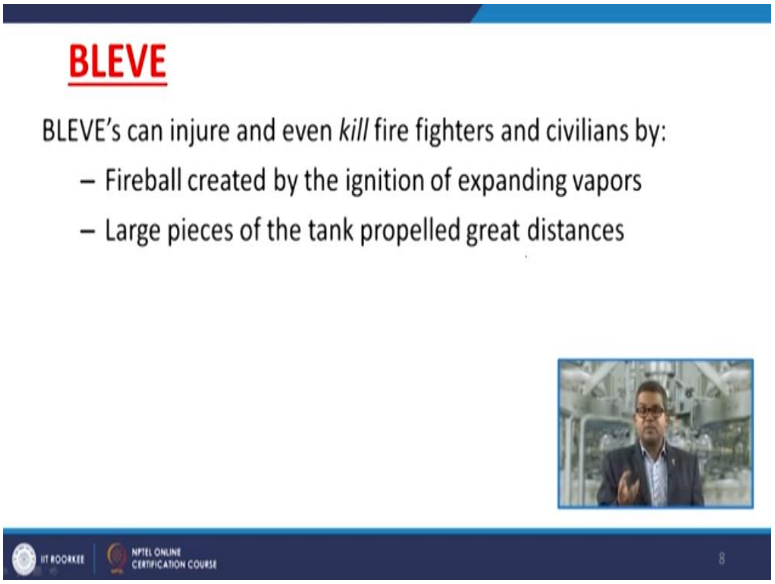

Now BLEVE can injure and even kill fire fighters and civilians by creation of fire ball, by ignition of expanding vapors, large pieces of the tank propelled great distances, because of the rupture small pieces may be generated because of the pressurized vessel rupture. Then these large pieces of the tank or small pieces of the tank may propel to and it may cause harm to the fire fighters or a nearby person those who are around that particular vessel.

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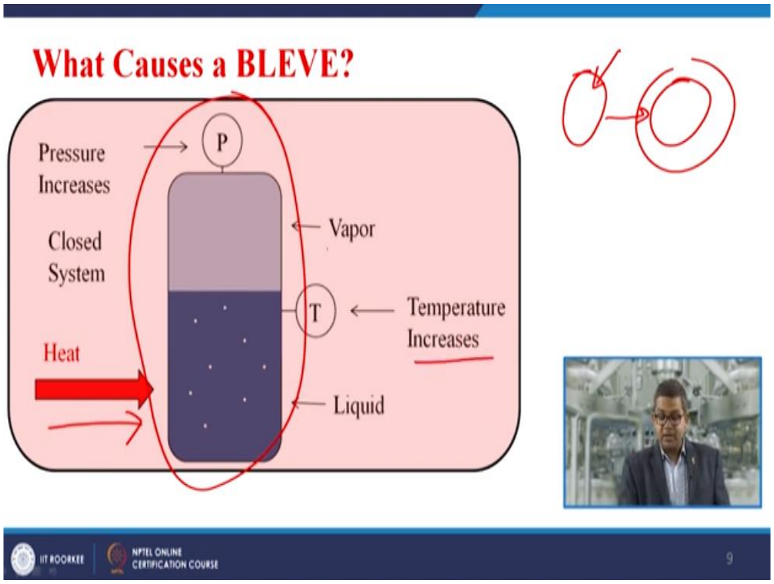

Now it is you can visualize the things through this figure, suppose we are working in a particular closed system and pressure increases and somehow it catches the heat just like in Jaipur one vessel caught the fire and heat propagated to the another vessel and this is being heated up. So by any means it catches the heat and the liquid though somehow temperature rises or temperature increases and the formation of vapors propagated.

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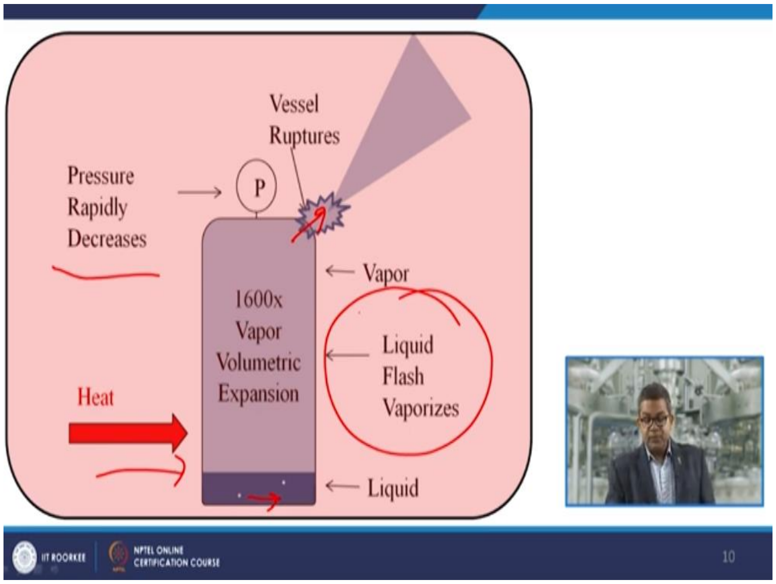

Since pressure increases rapidly and where the continuous addition of the heat there may be volumetric expansion of the vapors as well as since whatever liquid is there it is just above the boiling point, so almost 1600, 1700 or 1800 times of volumetric expansion experience and at this point the vessel ruptures. So liquid, whatever liquid is inside because it is at the higher temperature as well as the pressure, so liquid flashes and all flashed vapors they are having the tendency to escape to the atmosphere.

So this is again very, very destructive and again it may create a problem of confined or unconfined vapor cloud explosion and sometimes you would not be able to control it because of the excessive pressure being built up. As I told you that small or a large piece of vessel may be generated, this may create a harm to the parson those who are working around or those who may actuate or initiate safety devices. So by this way this is extremely dangerous and all the liquid sometimes all the liquid within the pressurized vessel may escape to the atmosphere and the problem will be extremely destructive in nature.

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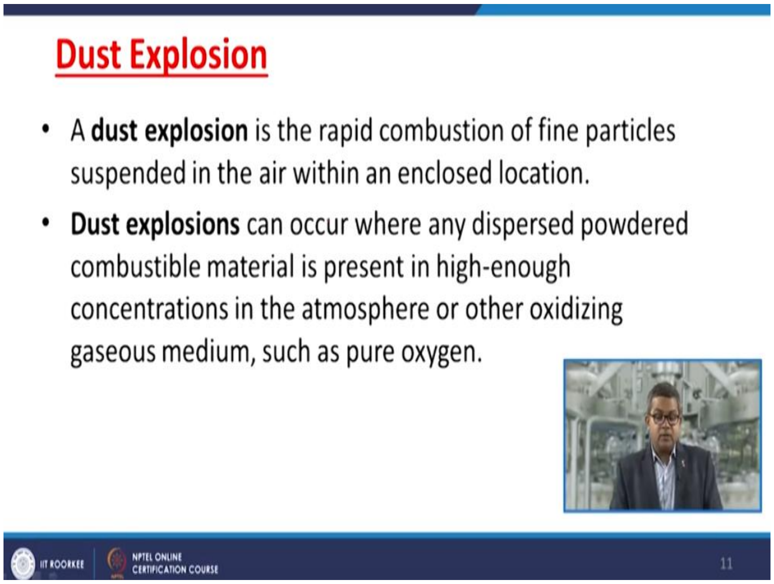

Now come to the third special case that is the dust explosion. Now the dust explosion is the rapid combustion of fine particles suspended in the air within an enclosed location, this can occur where any dispersed powered combustible material is present in high-enough concentrations in the atmosphere or other oxidizing gaseous medium such as pure oxygen.

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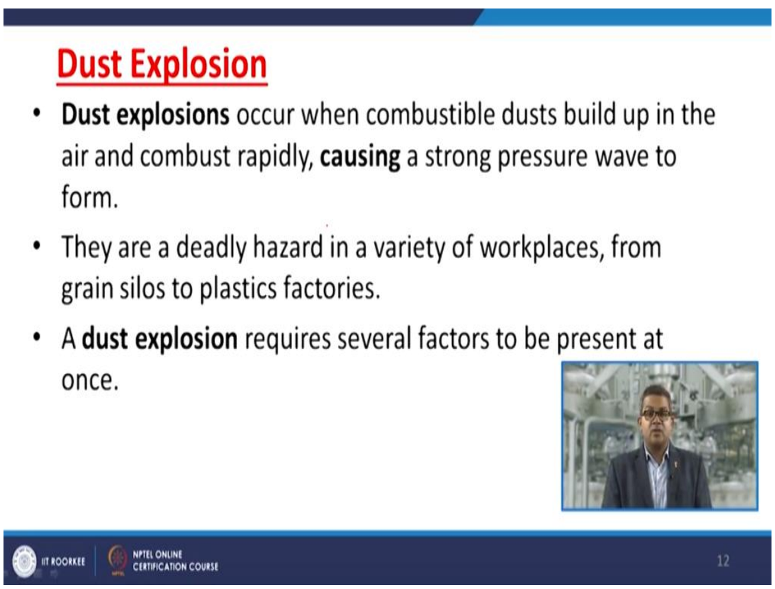

This occurs when the combustible dust build up in the air and combust rapidly causing a strong pressure wave to form and they are deadly hazard in a variety of workplace from grains silo to plastics factories or polymer factories etc, dust explosion requires several factors to be present at once.

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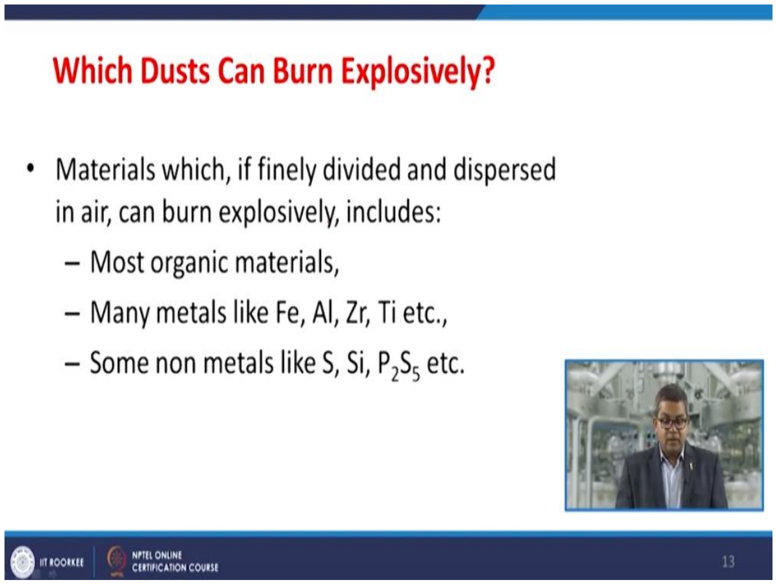

Now question arises that, which dust can burn explosively? So answer is material which if finally divided and dispersed in air can burn explosively, this includes most of the organic materials, many metals like iron, aluminum, etc, some of the non-metals like sulfur, silica, P_2S_5 etc.

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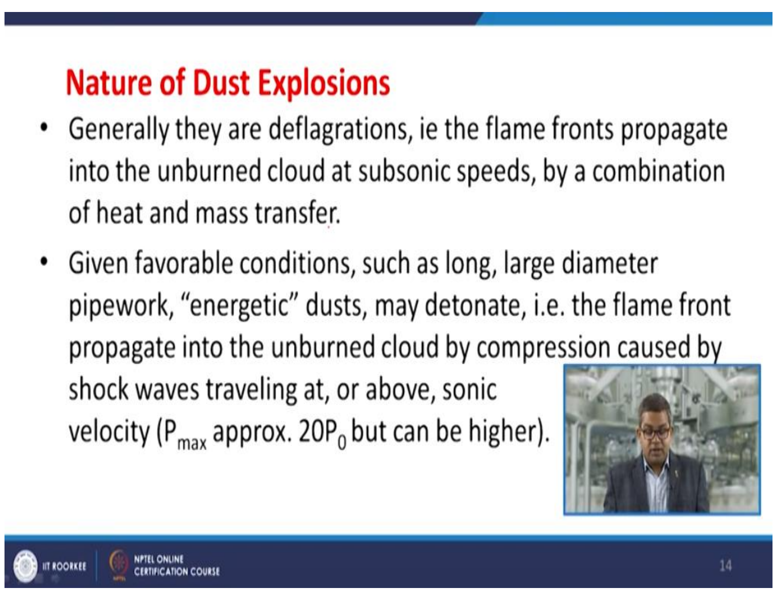

Now nature of dust explosion, so because we know that what kind of material can explode, can burn then we must know that what should be the or what is the nature of dust explosion. So generally they are deflagration not being detonation. So deflagration and that is the flame front propagate into the unburned cloud at subsonic speed by a combination of heat and mass transfer. Now given favorable conditions such as long large diameter pipework, energetic dust may detonate. That is the flame front propagate into the unburned cloud by compression caused by shockwaves travelling at or above sonic velocity.

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Now this may be, you can visualize this is silo or silo within the factory premises is there and dust explosion took place and it led to the fire.

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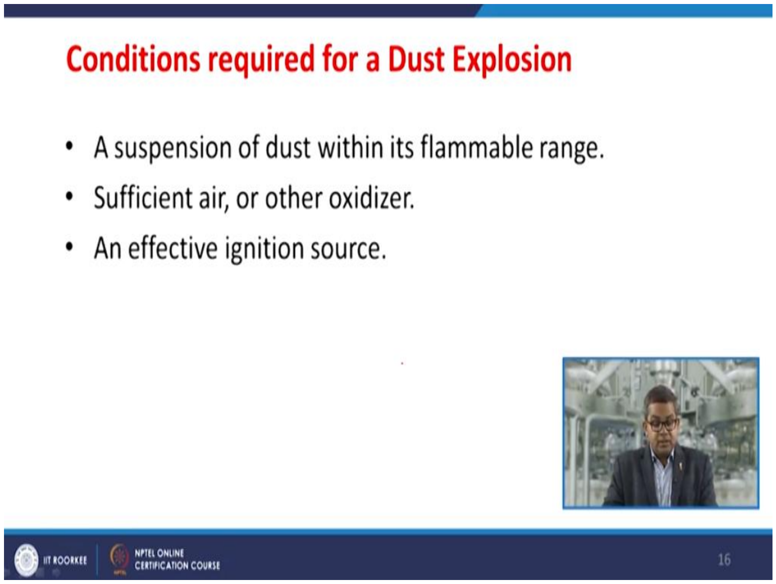

Now what are the conditions required for a dust explosion? Usually a suspension of dust within its flammable range, the sufficient air or other oxidizers and effective ignition source. So these 3 are the favorable conditions for dust explosion.

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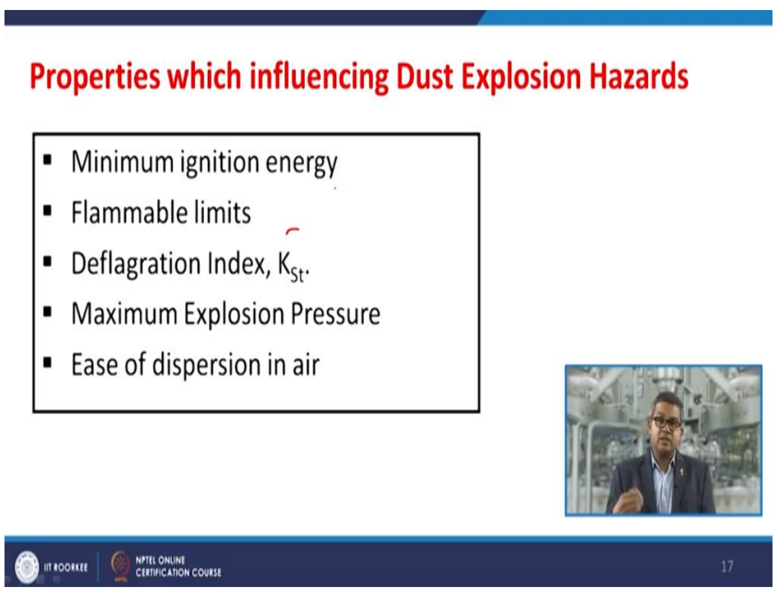

Now there are various properties which are influencing the dust explosion hazard, we have discussed some of the properties in the previous modules like minimum ignition energy. Flammable limits, deflagration index this is the new one, the maximum explosion pressure obviously this is desired because the rupture of vessel took place, ease of dispersion in air and sometimes the wind speed or wind inversion plays a very vital role in the ease of dispersion or the dispersion of the material in the air.

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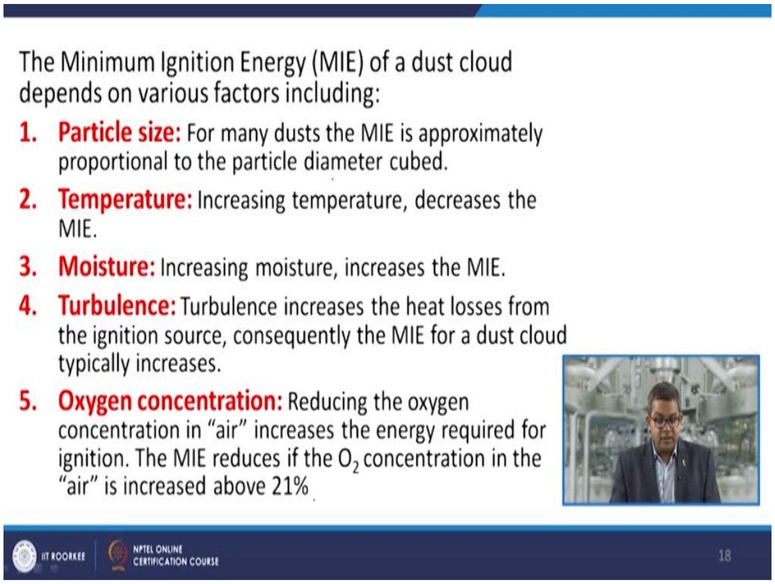

The minimum ignition energy of a dust cloud depends on various factors, they are particle size like for many dust and minimum ignition energy is approximately proportional to the particle diameter cubed, the temperature increasing temperature decreases the minimum ignition energy, the moisture the increasing moisture increases the minimum ignition energy so that you require a large quantity of energy or a bit higher energy required. So the turbulence the turbulence increases the heat losses from the ignition source.

And consequently the MIE for the dust cloud typically increases, so this is again very important, the oxygen concentration the reducing the oxygen concentration in air increases the energy required for ignition and MIE reduces if oxygen concentration in the air is increased above 21 percent.

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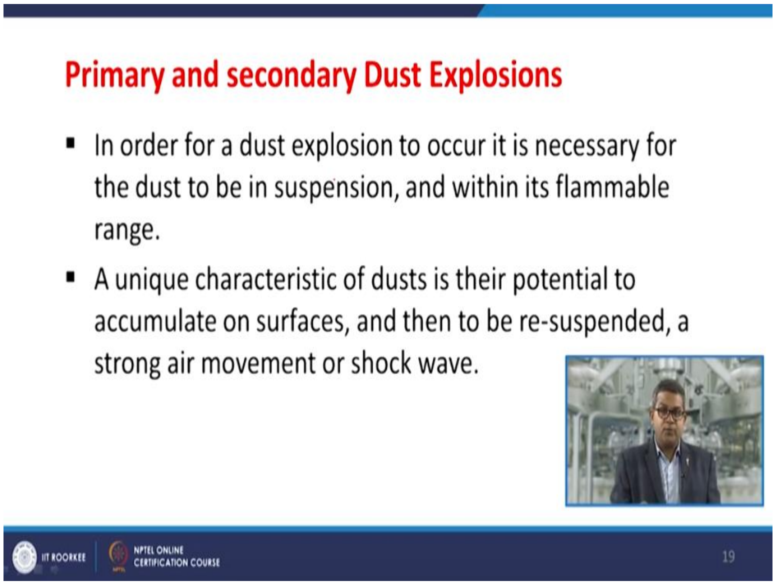

Now a there are 2 type of dust explosion, primary and secondary dust explosion. Now in order for a dust explosion to occur it is necessary for the dust to be in suspension and within its flammable range. You must know that what are the flammable range of that particular dust. A unique characteristics of dust is their potential to accumulate on surfaces and then to be re-suspended a strong air movement or a shockwave. Now we will discuss this particular aspect with the figure in subsequent slides.

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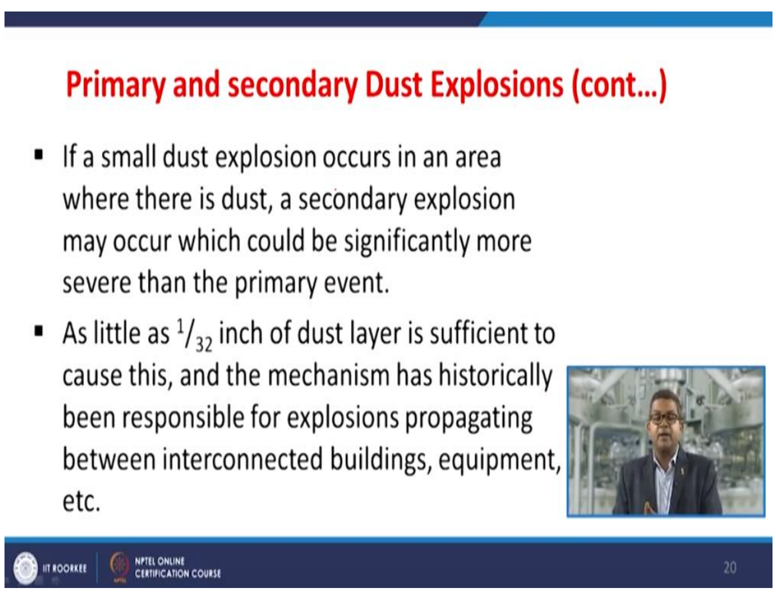

Now if a small dust explosion occurs in an area where there is a dust, a secondary explosion may occur which could be significantly more severe than the primary one. Now as little as 1 by 32 inch of a dust layer is sufficient to cause this one, we can see that what is the gravity of this particular aspect and the mechanism has historically been responsible for explosion propagating between the inter-connected building, equipment etc.

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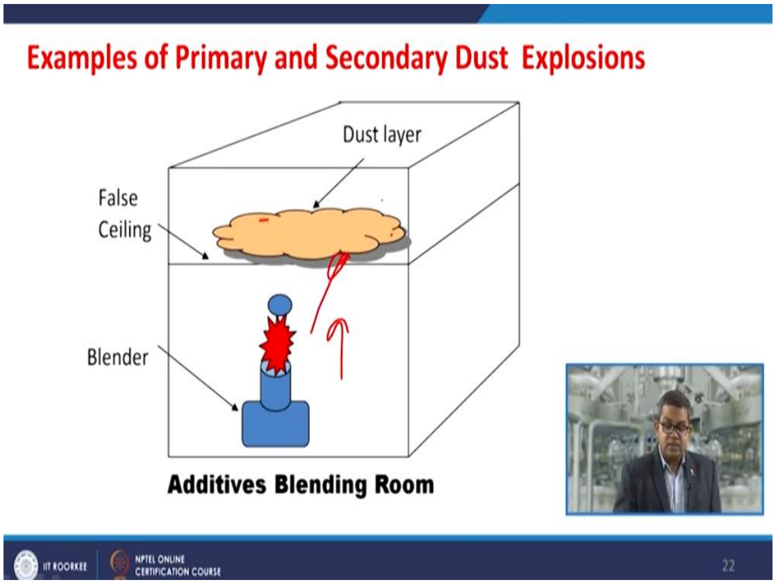

Now you can have a look of this particular figure, this is the best example of primary and secondary dust explosion. It have a blender, the additive blending room; this particular room is equipped with the false ceiling and there is a small quantum of dusty layer. This is accumulated over the period of time, now this while working this blender with this blender a certain quantity of fine particles is being generated.

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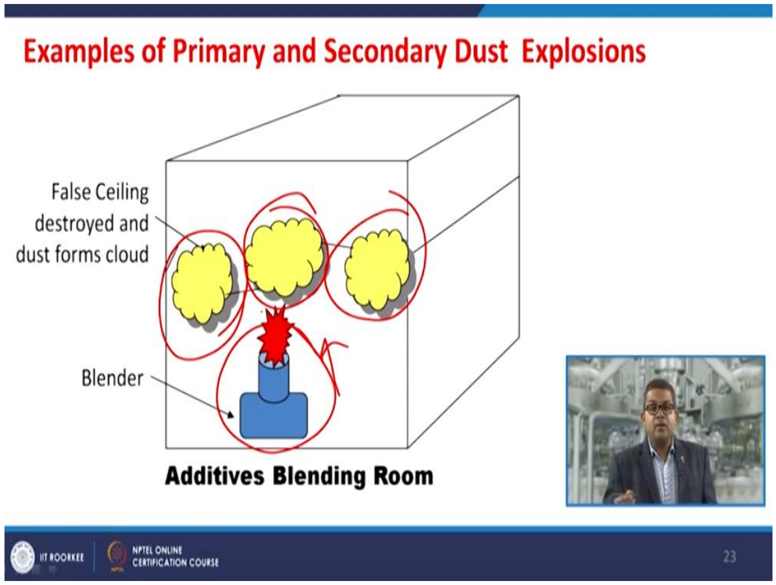

Now over the period of time these fine particle they are accumulated over this dust layer. Then somehow this false ceiling destroyed and these dust they forms the clouds just like this. You do have a blender, there may be chance that these dusts are of ignitable material or there may be a chance that, so this is creating a pressure front which may cause the severity of the problem.

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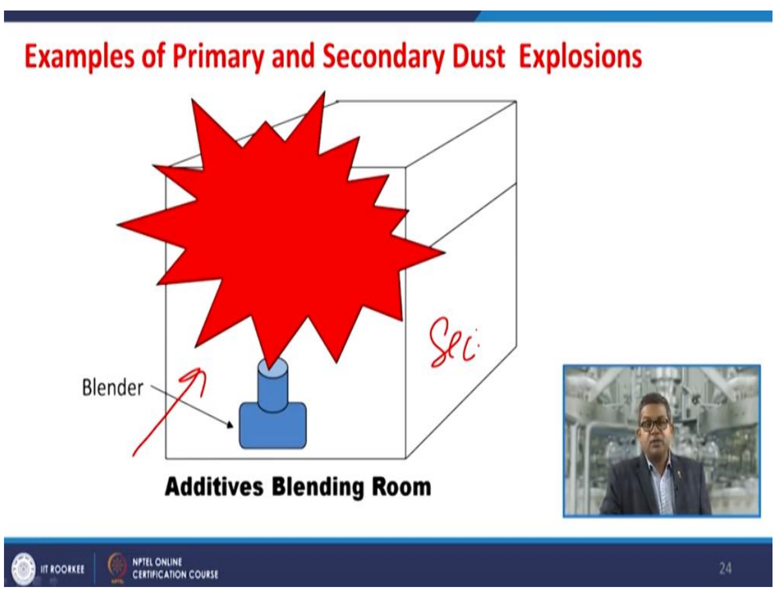

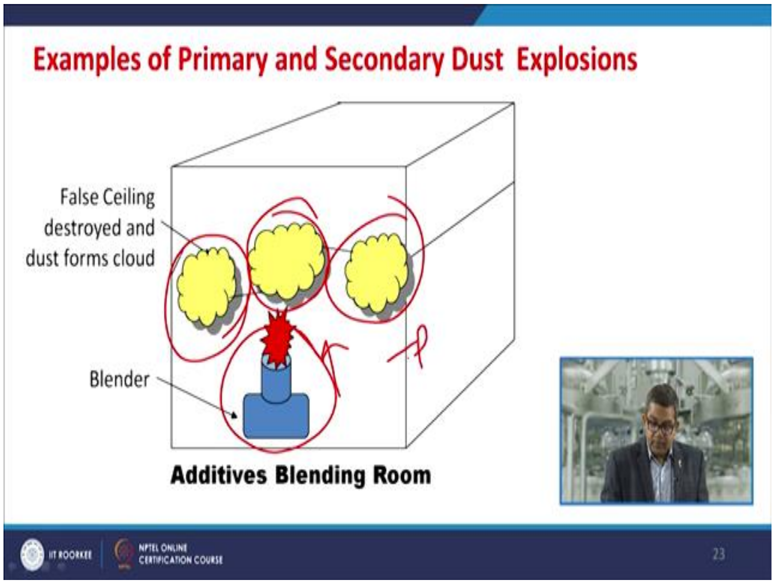

So in due course of time with the effect of pressure front, with the effect of accumulation of some more desk, with the effect of the collapse of this false ceiling there is a chance of dust explosion. So this particular thing is the primarily one and this one is the secondary one. So whenever we are dealing such type of a scenario do not ignore the importance of deposition of finally divided dust at the false ceiling or some other location which are not at the closed vicinity of or the close visibility of ourselves.

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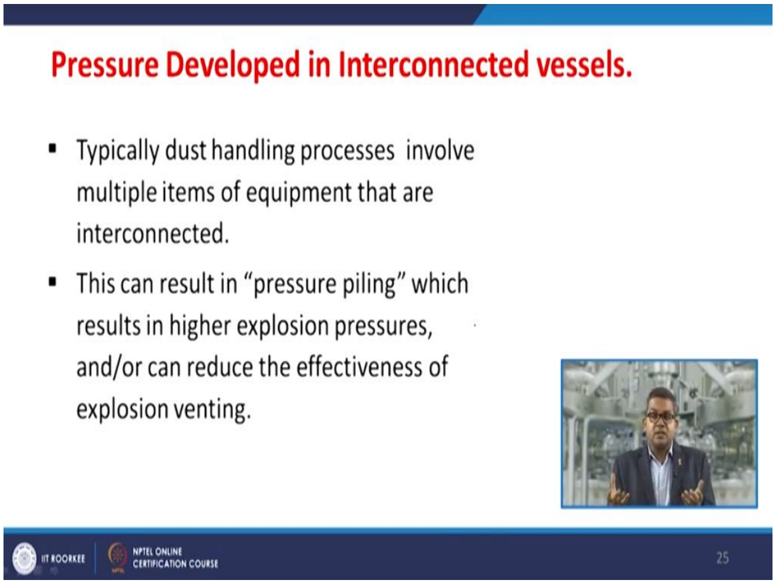

Sometimes we may experience the problem of dust explosion in interconnected vessels. Now typically dust handling processes involve multiple items of equipment that are interconnected. So this can result the pressure piling which results in higher explosion pressure and reduces the effectiveness of explosion venting.

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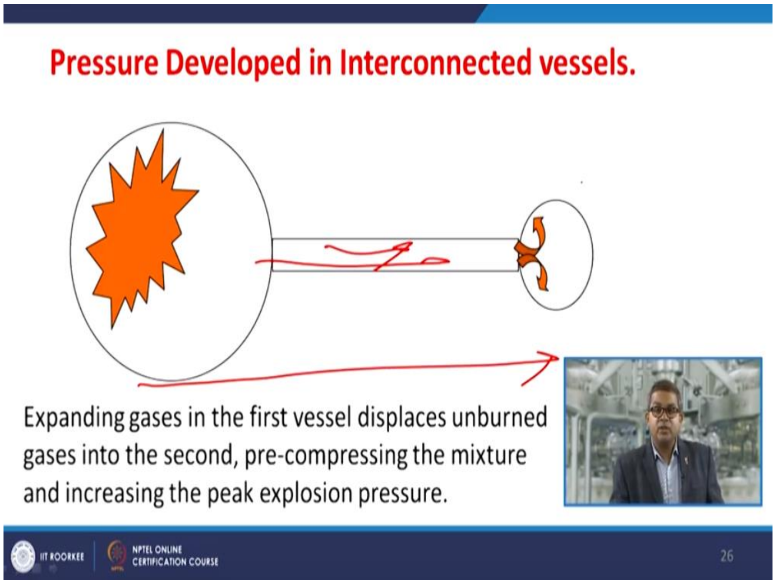

Now how it can happen? Now this is again the 2 scenario, they are interconnected, this device and certain quantity of dust is being accumulated over here. So expanding gases in the first vessel they displace unburned gases into the second one from here and pre-compressing the mixture and increasing the peak explosion pressure because they are well interconnected. So by this way there may be a chance that the dust or pressure whatever is accumulated being exploded.

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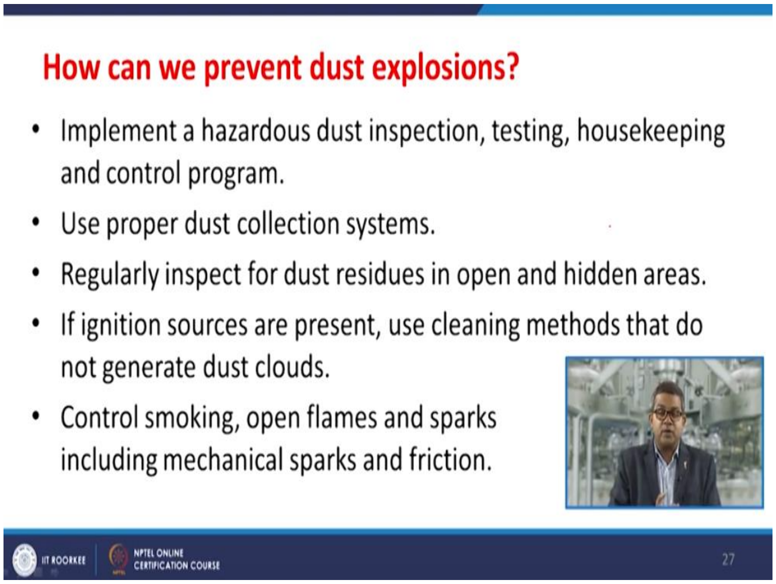

Now question arises that how can we prevent the dust explosion? It can be prevented by the implementation or implement a hazardous dust inspection, testing protocol, proper housekeeping methodologies and control program. I gave you an example that sometimes you ignore the dust deposited in the false ceiling and if we are performing some specialized activities then definitely it creates a problem. So one must use the proper dust collection system, we must regularly inspect the for dust residues in open and hidden areas. Now if ignition sources are present, use cleaning methods that do not generate dust clouds, you must control the smoking, open flames, spark including the mechanical sparks and friction.

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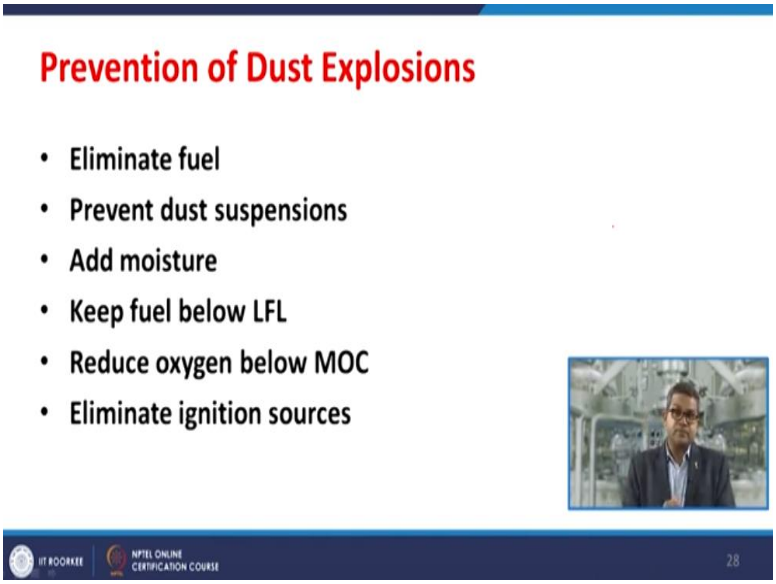

Other part of the prevention methodology includes the elimination of fuel. We must eliminate and just imagine the scenario the dust say metal dust is there and that is supported by the generation of a fuel, then definitely the results would be more destructive. You must prevent the formation of any dust suspension; try to add more and more moisture. Now reason is that as earlier discussed that if moisture increases then minimum ignition energy increases, so the chances of explosion or chances of fire is on the lower side.

So keep fuel below the lower flammability limit, obviously it is desirable because and do not rely upon the upper flammability limit, so keep fuel below lower flammability limit. Reduce the supply of oxygen to below minimum oxygen concentration, this is the primary required so that it does not match the FLF and UFL requirement or it does not close to the minimum oxygen concentration. This is just to avoid any kind of fire or dust explosion, try to eliminate ignition sources because you cannot eliminate completely all the ignition sources.

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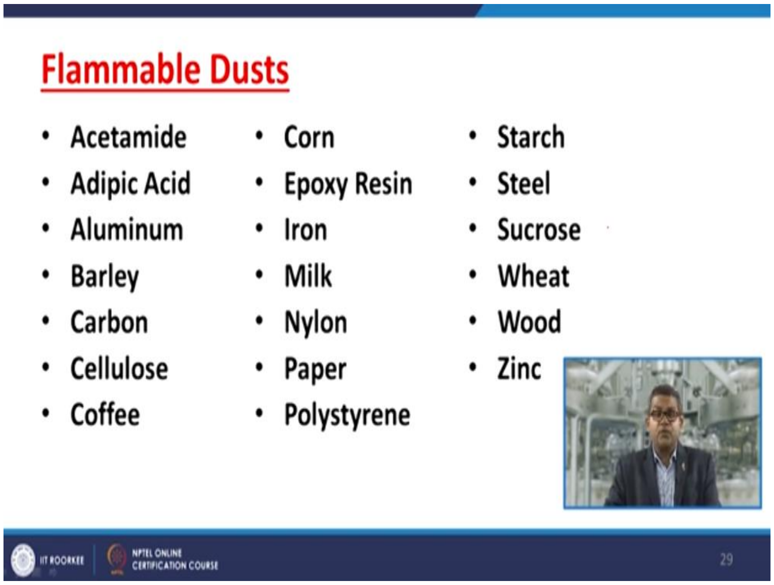

There are various type of dust like acetamide, adipic acid, aluminum, barley, carbon, cellulose, coffee, corn, epoxy resin, iron, milk, nylon, paper, polystyrene, starch, steel, sucrose, wheat, wood, zinc etc. So dusts are in N number of things, only thing is that you need to identify that which can contribute what.

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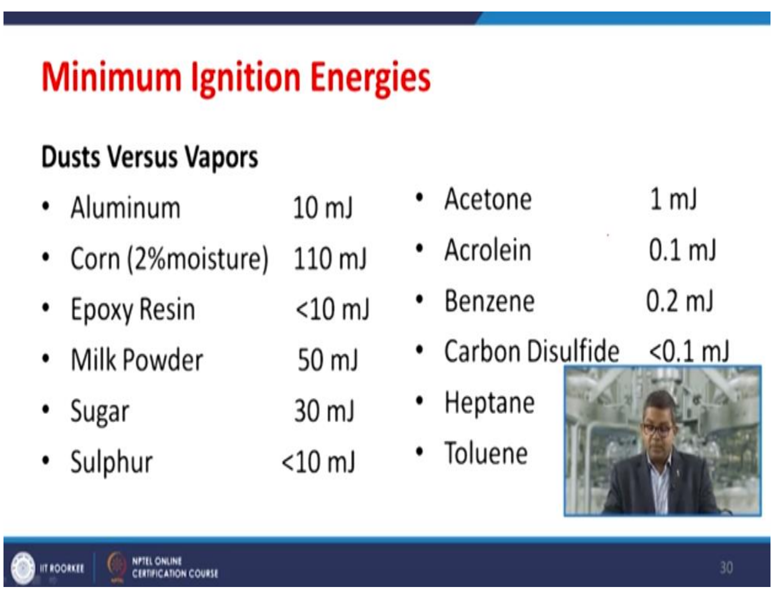

Now here we have enlisted certain minimum energies of dust versus vapors. So aluminum like aluminum 10 millijoule; corn 2 percent moisture, 110 millijoule; epoxy, milk powder, sugar sulfur, acetone, acrolein, benzene, carbon disulfide, heptane, toluene, so you can have this particular information from various literature, different handbooks. So these are the standard things so that you can avoid the scenario of fire and explosion. So in this particular module we have discussed about the BLEVE.

We have discussed about the dust explosion and the gravity of dust explosion, we have discussed about the BLEVE concept because BLEVE is the Jaipur accident is again a best example of BLEVE. So, whenever you are performing any kind of safety analysis, whenever you are performing any kind of accidental investigation, do not forget you must know that what can contribute want. Thank you very much.