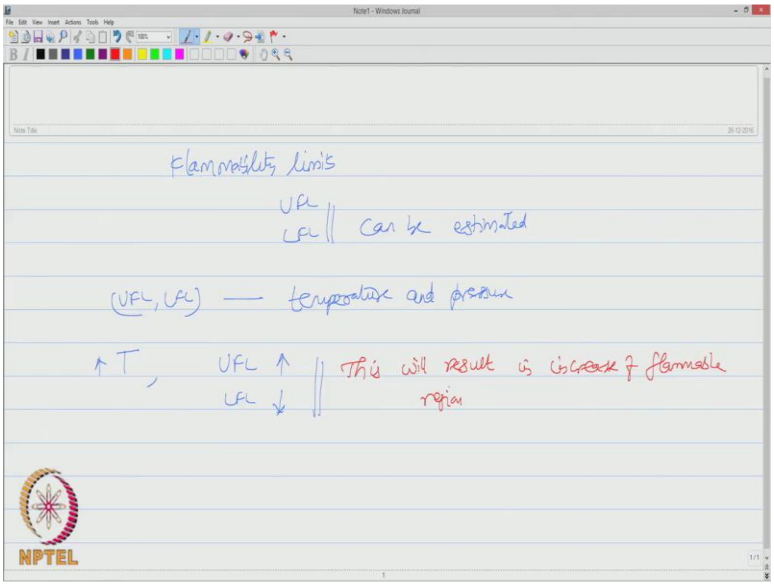
Offshore structures under special loads including Fire resistance
Prof. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module – 03
Fire Resistance
Lecture – 40
Explosion – I

Friends, we will continue with the discussion on lectures related to Fire Resistance, let us look into details of Explosion in lecture 40.

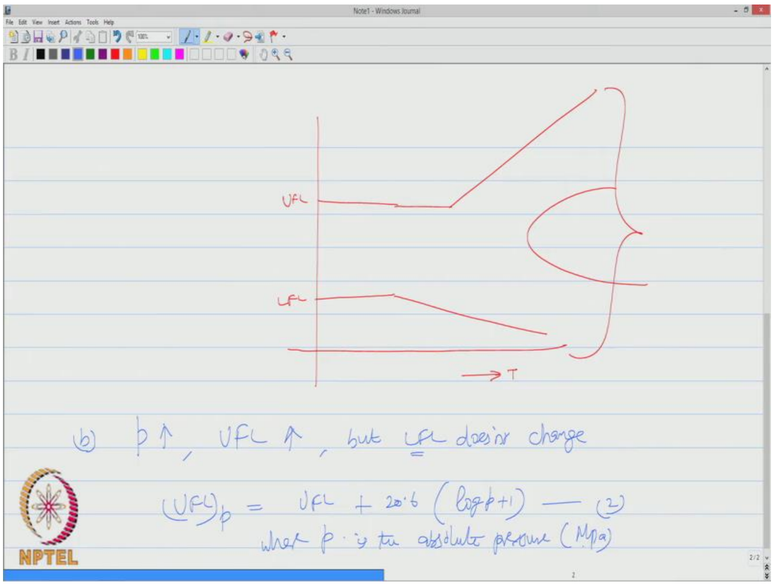
(Refer Slide Time: 00:33)



We already said that flammability limits can be experimentally determined using open cup method and the flammability constants a b c can be evaluated based on which upper flammable limit and lower flammable limit of a mixture can be estimated.

Now, these flammable limits UFL and LFL are also dependent on temperature and pressure; when temperature increases upper flammable limit increases and lower flammable limit decreases and this will result in increase of flammable region typically if you look at the curve LFL decreases with increase in temperature and UFL increases with increase in temperature.

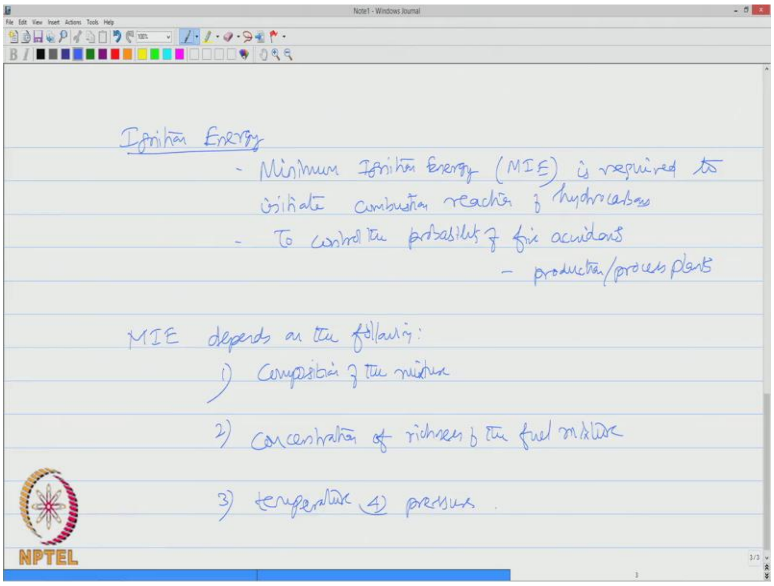
(Refer Slide Time: 02:02)



So, this is upper flammable this is lower flammable limit therefore, is may auto ignition therefore, I can say the flammable region increases with increase in temperature as far as pressure is concerned pressure when the pressure increases upper flammable limit increases, but lower flammable unit does not change.

So, change in pressure does not affect the lower flammable limits. So, upper flammable limit at any pressure p can be given by upper flammable limit of the mixture at atmospheric pressure, plus 20.6 log p plus 1. So, that is the second equation we have, where p is the absolute pressure in mega Pascal.

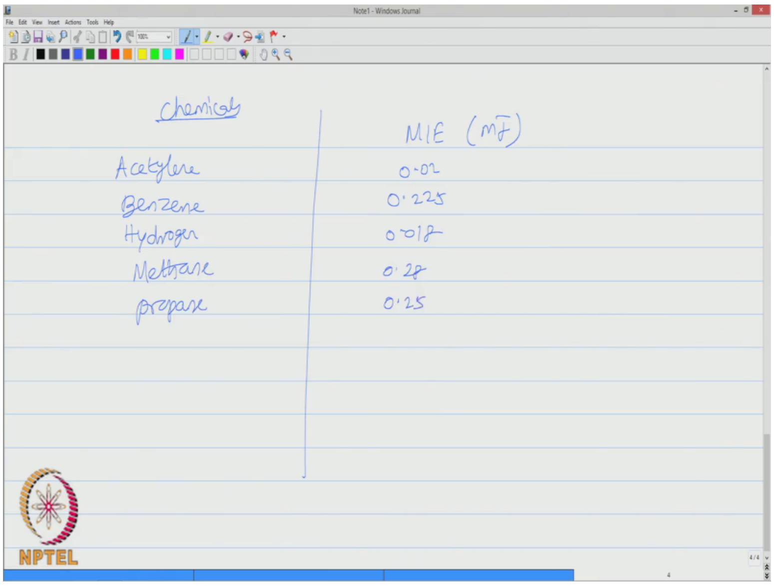
(Refer Slide Time: 03:55)



As we said fire will cause release of energy, which we call as ignition energy related to ignition energy there is a very important glossary which we need to understand there is something called minimum ignition energy, which we call MIE, minimum ignition energy is required to initiate combustion reaction of hydrocarbons. This is one important tool which can be used to control the probability of fire accidents, which are very common in production and process plants; interestingly the minimum ignition energy depends on the following factors.

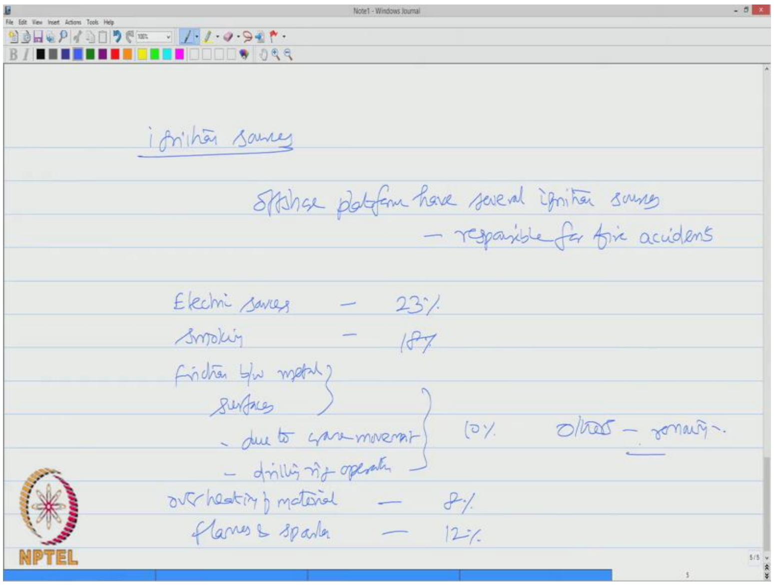
One it depends upon the composition of the mixture, it means the fuel mixture; two it depends upon the concentration of richness of the fuel mixture; three it depends of course, on temperature and pressure.

(Refer Slide Time: 06:18)



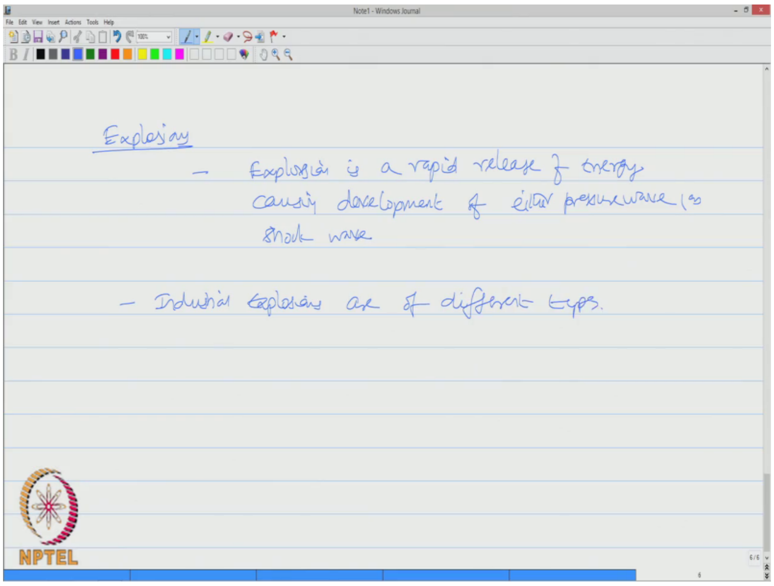
Let us look simple reference examples of different chemicals and their corresponding minimum ignition energy, let say Acetylene, Benzene, Hydrogen, Methane and Propane.

(Refer Slide Time: 07:05)



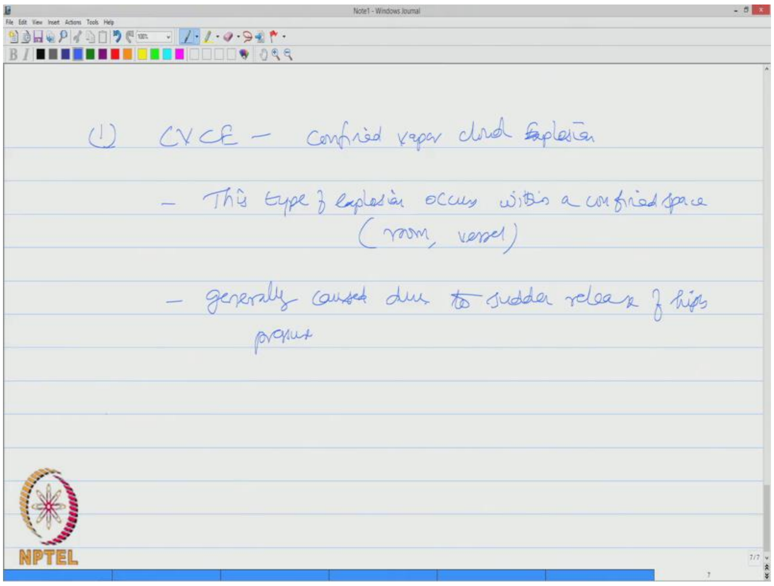
Let us ask a question what are the possible ignition sources we have in offshore platforms? Offshore platforms have many ignition sources and they are responsible for fire accidents, as statistical information the electric sources present in the platform amounts to about 23 percent, smoking amounts to about 18 percent, friction between metals metal surfaces the examples can be due to crane movement, due to drilling rig operation etcetera this amounts to about 10 percent. Overheating of material because of constant high temperature process amounts to about 8 percent, flames and sparks amount to about 12 percent and others can be remaining.

(Refer Slide Time: 09:03)



Let us ask a question more in detail about explosions. We all said already that explosion is a rapid release of energy causing development of either a pressure wave or a shock wave. Industrial explosions are of different types; let us see one by one. The first one in the list is CVCE what we called confined vapor cloud explosion.

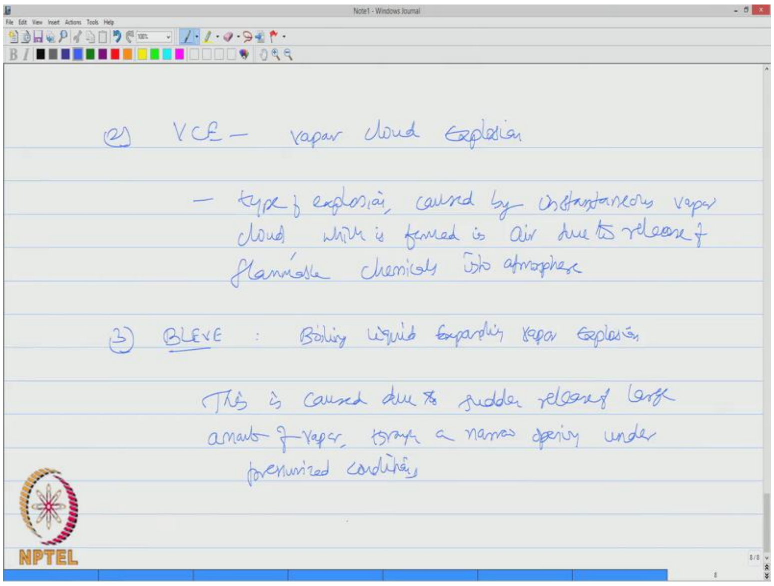
(Refer Slide Time: 10:00)



This type of explosion occurs within a confined space, it can happen inside a room, it can happen inside a pressure vessel etcetera.

They are generally caused due to sudden release of very high pressure.

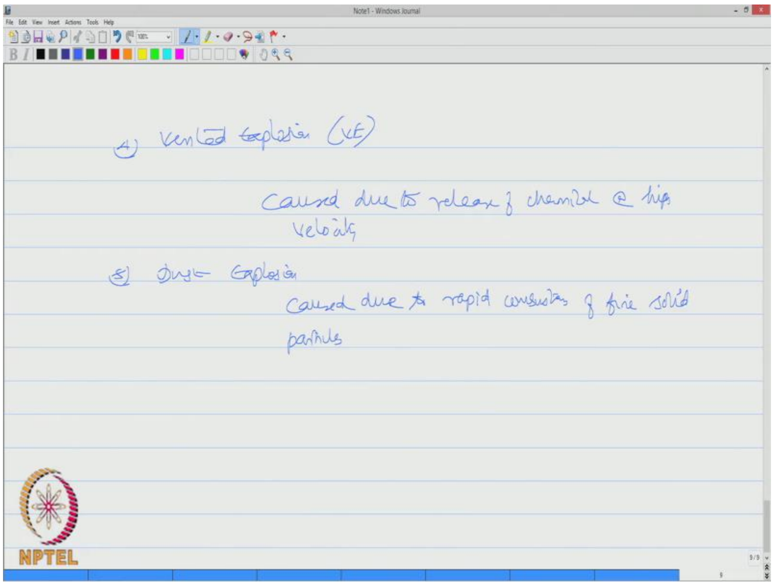
(Refer Slide Time: 11:03)



The second one is called VCE, which is vapor cloud explosion. This is a type of explosion caused by instantaneous vapor cloud, which is formed in air due to release of flammable chemicals into atmosphere.

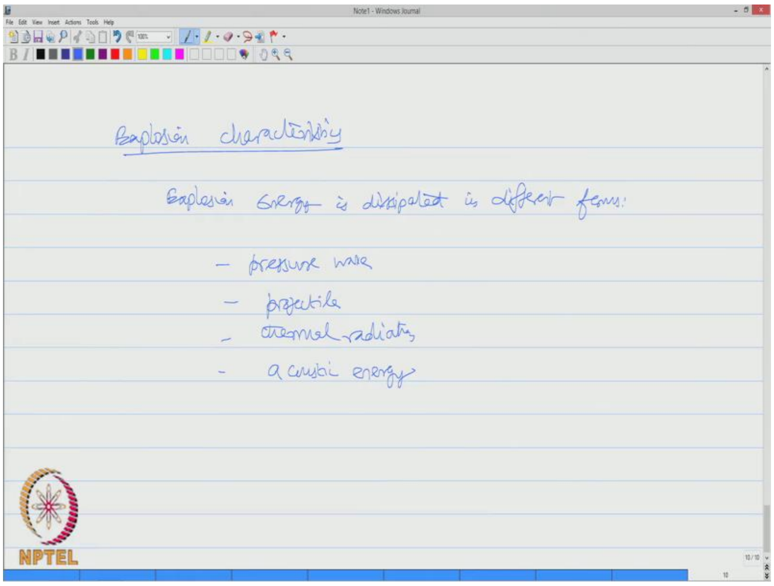
The third one is BLEVE; which is boiling liquid expanding vapor explosion; this is caused due to sudden release of large amount of vapor through a narrow opening under pressured conditions.

(Refer Slide Time: 13:03)



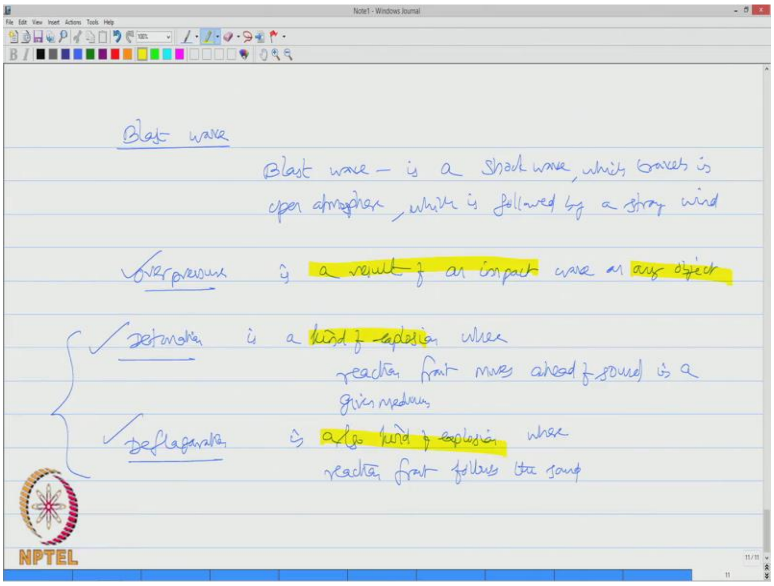
The forth one is vented explosion which is VE; this is caused due to release of chemical at high velocity. The next variety is what we call dust explosion; this is caused due to rapid combustion of fine solid particles.

(Refer Slide Time: 13:59)



Let us now look into the explosion characteristics; explosion energy is dissipated in different forms, it could be in the form of a pressure wave release, it could be in the relief of a projectile, it could be appearing in the form of a thermal variation and can also be in the form of release of acoustic energy. To understand the expression energy, let us try to basically understand more in detail about the blast wave.

(Refer Slide Time: 15:02)

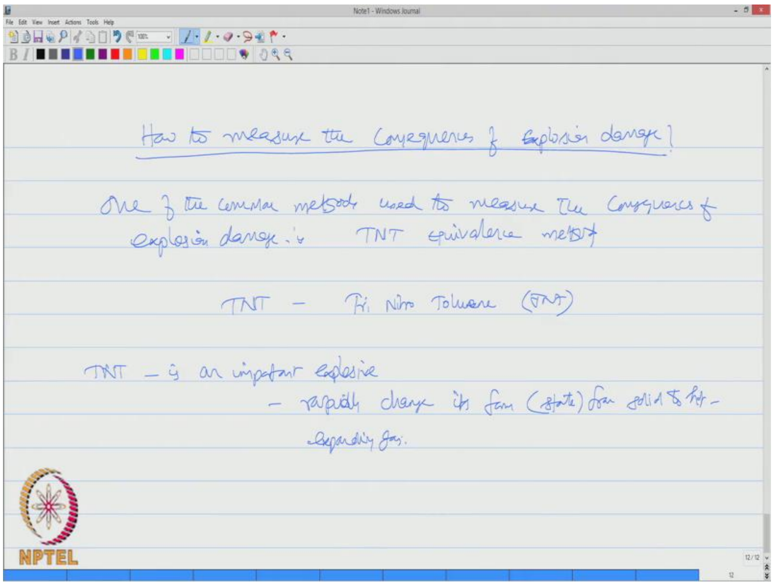


What is a blast wave? Blast wave is essentially a shock wave, which travels in open atmosphere which is generally followed by a strong wind. Over pressure is actually a result of an input wave causing an impact there is an impact wave on any object that is what we call as over pressure. Over pressure essentially is a result of any impact wave on any object.

Detonation is a kind of explosion, where the reaction front moves ahead of sound in a given medium, it is of a very high velocity; deflagration is also a kind of explosion, where the reaction front follows the sound. So, here the velocity is higher than sound we call detonation, if the velocity of propagation is lesser than sound we call that as deflagration, both of them are kind of explosions, which will cause extensive damage on a given body in a given medium.

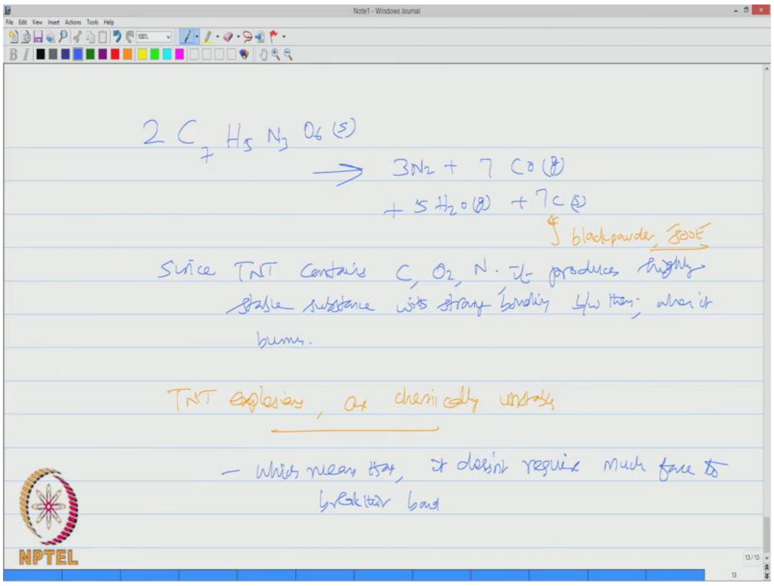
So, question now comes to mind is, how to measure the consequences of explosion damage?

(Refer Slide Time: 18:04)



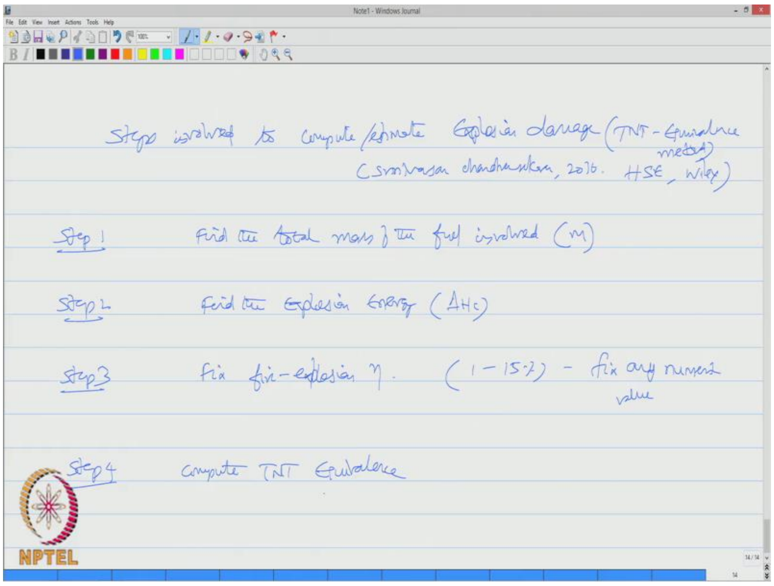
Because that is very necessary in risk assessment; one of the common methods used to measure the consequences of explosion damage is TNT equivalence method. So, TNT is Tri Nitro Toluene; TNT is an important explosive which can rapidly change, which can rapidly change its form or state from solid to hot expanding gas.

(Refer Slide Time: 19:53)



The reaction looks like this H 5 N 3 O 6 s is actually 3N 2 plus 7 C o g, plus 5H 2 o g, plus 7 C s. So, this is what we call as a black powder is a residue of the reaction, which is called as soot. Interestingly since TNT contains carbon, oxygen, nitrogen, it produces highly stable substance with strong bonding between them when it burns; however, TNT explosions are chemically unstable, which means that it does not require much force to break the bond.

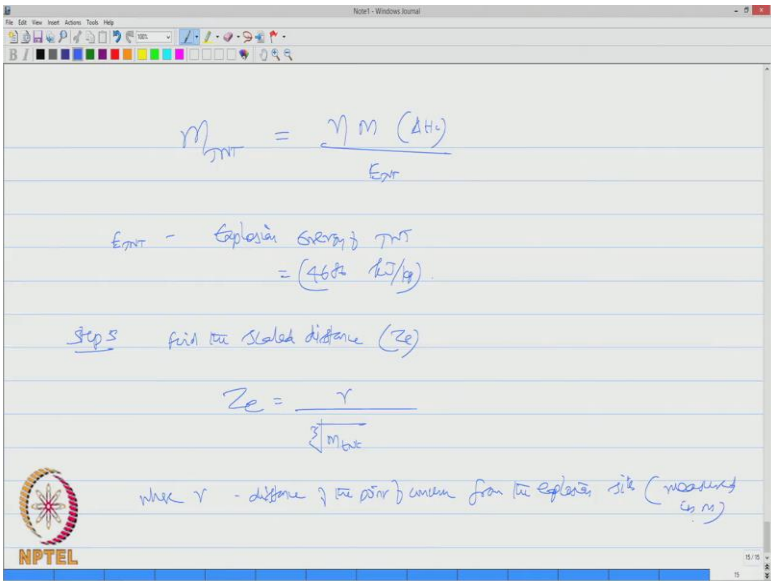
(Refer Slide Time: 22:10)



Let see what are the steps involved to compute or let say estimate explosion damage using TNT equivalence method, one can refer this to my book 2016 HSe, which is published by Wiley and sons, there are different steps involved.

Step number one find the total mass of the fuel involved in the reaction, let say in terms of we call that as M; step number two find the explosion energy of the mixture and the heat contributed or released from this process. Step number three fix something called fire explosion efficiency, this can vary anywhere from 1 to 15 percent you can fix up any number.

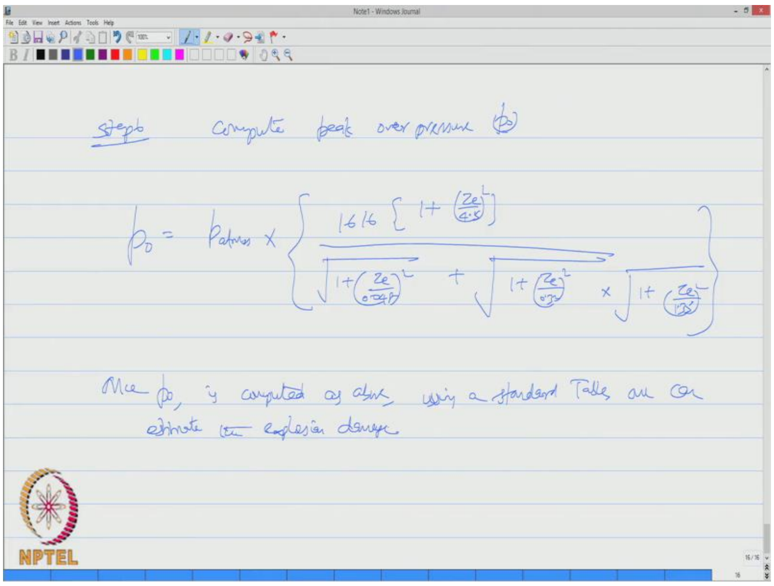
(Refer Slide Time: 24:27)



In step number 4 we need to compute TNT equivalence. So, m TNT is efficiency m delta H c, which we have computed divided by E TNT, E TNT is explosion energy of TNT which is 4686 kilo joules per kg.

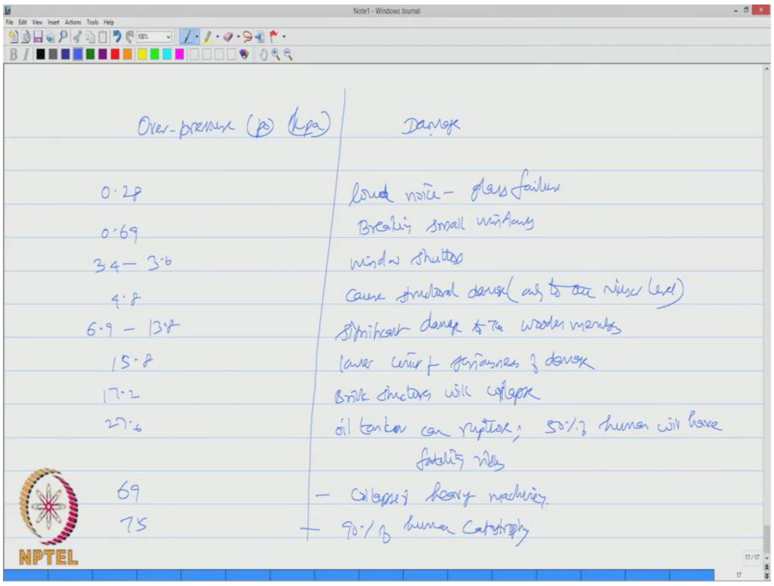
In step number 5 find the scaled distance which is called Z e and Z e can be given by this relation r by cube root of m TNT; where r is the distance of the point of concern from the explosion site measured in meters.

(Refer Slide Time: 26:03)



Then in step number 6, you are interested to estimate the damage so let us compute something called peak over pressure is P 0. P 0 can be given by this equation P at mas, multiplied by 1616, 1 plus Z e by 4.5 square root of 1 plus Z e by 0.048 square, plus root of 1 plus Z e by 0.32 the whole square multiplied by 1 plus Z e by 1.35 the whole square equation number. So, once over pressure P is computed as above using a standard table, one can estimate the explosion damage.

(Refer Slide Time: 28:10)

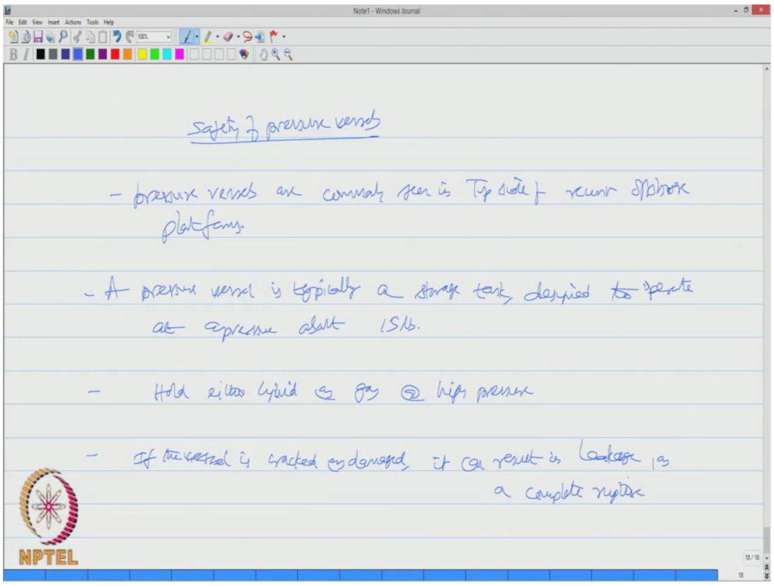


The table says over pressure P 0 in kilo Pascal say the damage caused. So, once we estimate the P 0 let say if it is a 0.28 then the damage will be you will hear a loud noise and there can be a glass failure of any window panes etcetera. If it is 0.69 it can even break small windows, if it is between 3.4 to 3.6 it can even damage window shutters.

If it is anywhere at 4.8 it can cause structural damage, but only to the minor level; the next value could be 6.9 to 13.8 which is pretty high, this will cause significant damage to the wooden members, if it is 15.8 then it has got or it has reached, lower limit of seriousness of damage.

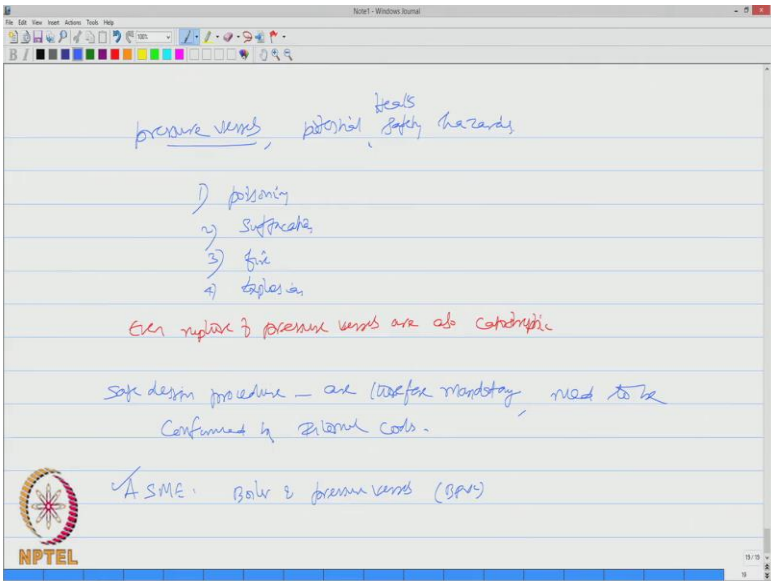
On the other hand if it is further increased to 17.2, brick structures will collapse. If it is further extended 27.6, oil tankers can rupture; more than 50 percent of the human will be facing or will have fatality risks. If it is as high as 69 even this can cause collapse of heavy machinery, if it is further to 75, it can result in more than 90 percent of human Catastrophy.

(Refer Slide Time: 31:36)



With this background let us extend the discussion for safety of pressure vessels, generally pressure vessels are common in top sides of recent offshore platforms, a pressure vessel is typically a tanker a storage tank designed to operate at a high pressure at a pressure about 15 pounds. Generally pressure vessels hold either liquid or gas at high pressure that is why they are called pressure vessels. If the vessel is damaged or cracked it can result in leakage or a complete rupture.

(Refer Slide Time: 33:44)

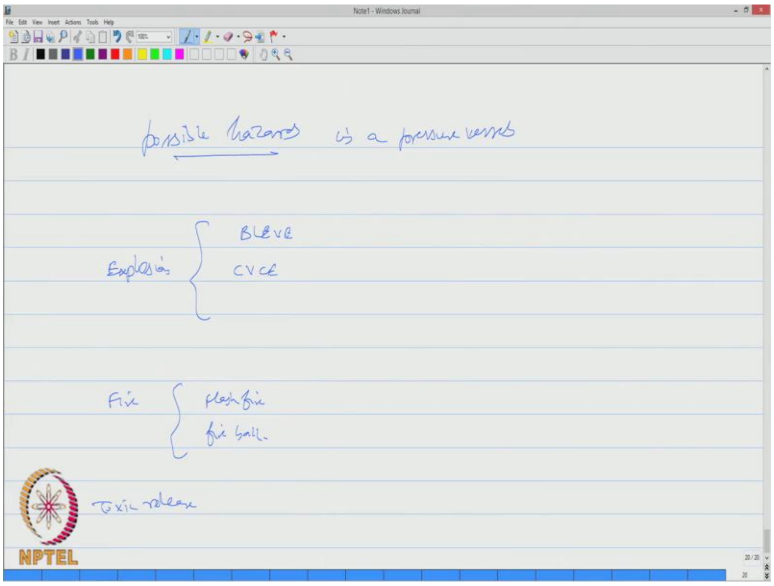


If you look at the pressure vessels which are one of the important candidates of explosion, there are different potential health safety hazards; one could be poisoning, two could be suffocation, three could be fire and fourth can be explosion.

Sometimes even ruptures of pressure vessels are also catastrophic. Safe design procedures are therefore, mandatory and therefore, mandatory and need to be confirmed by international courts.

ASME is a typical code it a code for boiler and pressure vessels, what we call BPVC code, one can use this as a standard reference to understand the limits of pressure vessels under the given operating temperature and pressure.

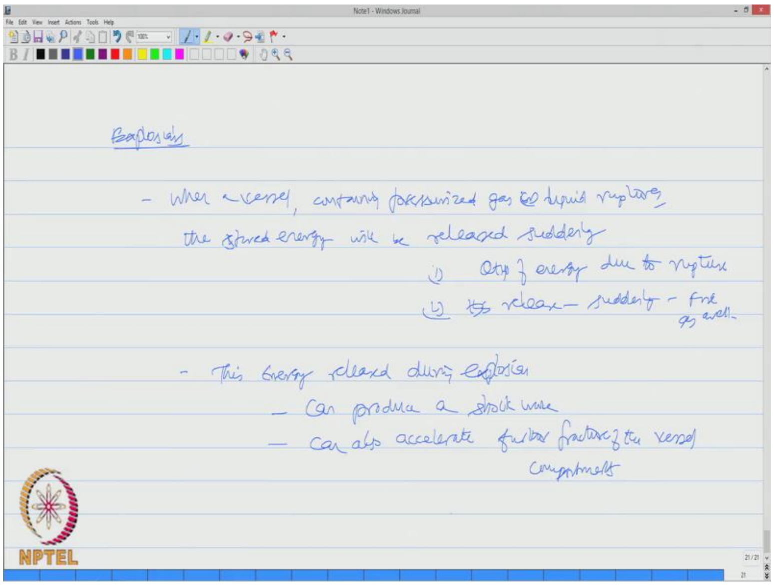
(Refer Slide Time: 36:12)



Let us then open a question called what are the possible hazards in a pressure vessel? Because pressure vessels are inherent part of toxic platforms, which are like semi submersibles, drill ships etcetera.

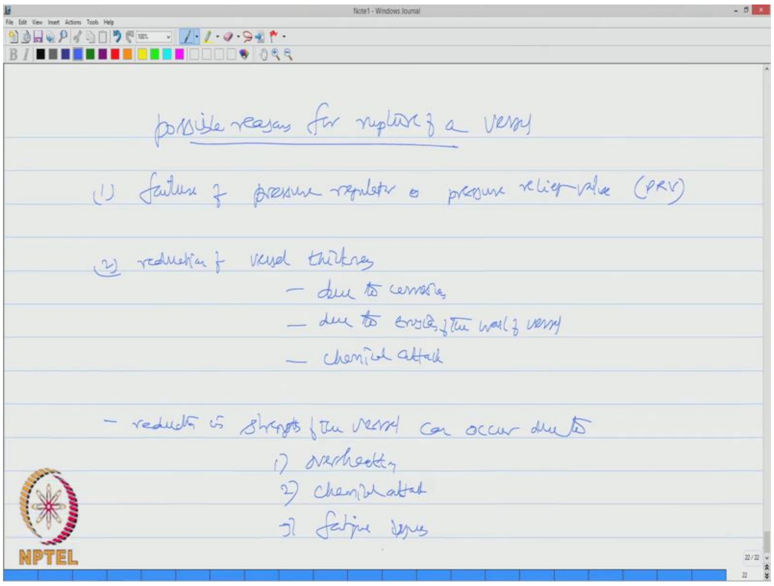
So, possible hazards could be 2; one could be explosion, other of course could be fire. Explosion will result in BLEVE and CVCE whereas; fire will result in flash fire and fire ball. In addition the third one could be a toxic release which can be directly computed based upon the Dows equation, which we discussed in the previous lectures.

(Refer Slide Time: 37:18)



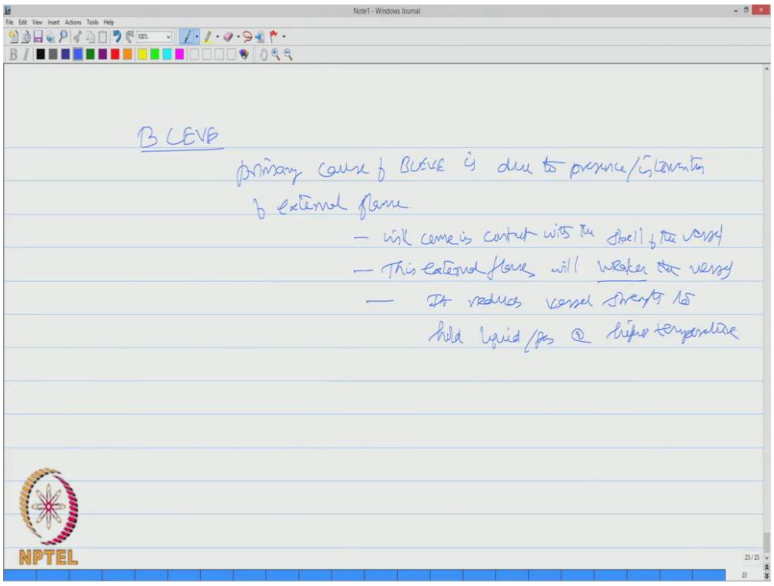
Let us try our understanding to know more about explosions; what is an explosion? When a vessel containing pressurized gas, it can be even a liquid ruptures if it ruptures, the stored energy will be released suddenly. So, there are two aspects here, one aspect is the quantity of energy released due to rupture; the second issue is this release happen suddenly and any sudden release will result in fire as well, this energy released during explosion can produce a shock wave it can also accelerate further fracture of the vessel compartments.

(Refer Slide Time: 39:25)



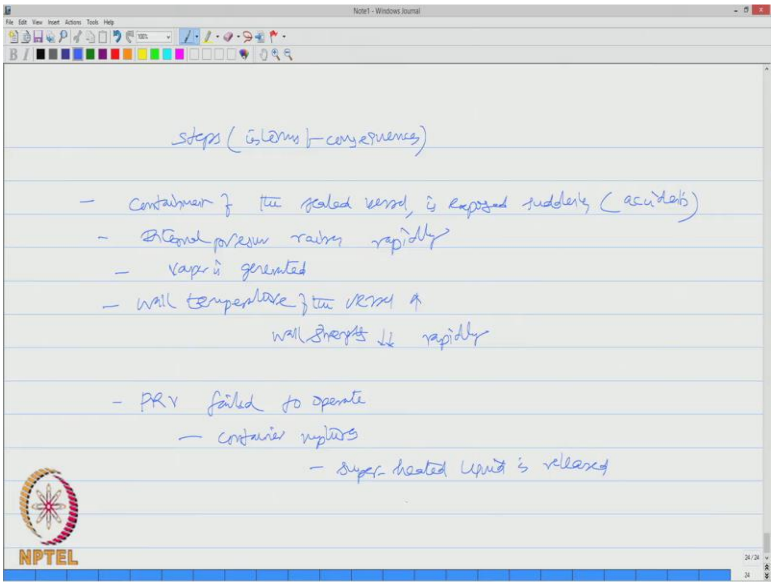
Let us ask a question what are the possible reasons for rupture of a vessel? Because if we know this reasons one can design the pressure vessel such that these reasons responsible for explosion or fire can be kept to the minimum. One it can occur due to failure of pressure regulator or a pressure relief valve PRV; can also occur resulting from reduction of vessel thickness. Reduction of vessel thickness can happen due to corrosion, due to erosion of the wall and due to chemical attack. Reduction in strength, strength of the vessel can also occur due to overheating, due to chemical attack and of course, due to fatigue issues.

(Refer Slide Time: 41:38)



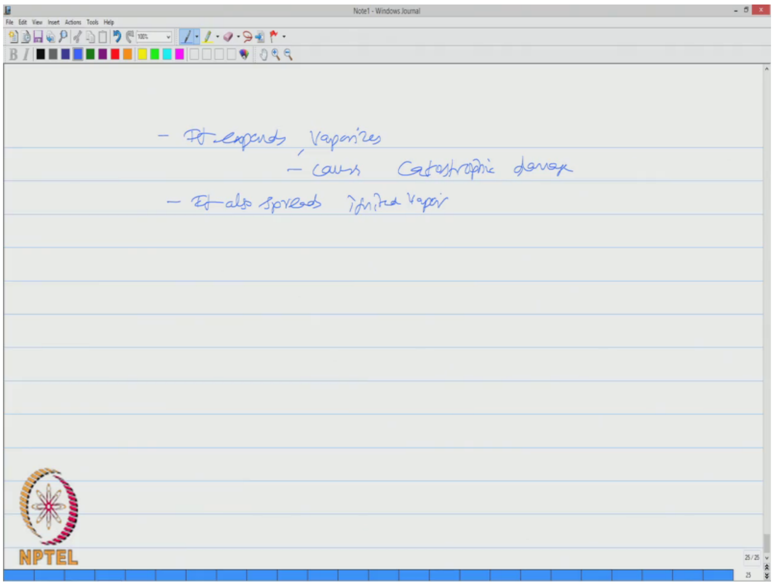
In explosion let us take up an important terminology which we discussed just now BLEVE primary cause of BLEVE is due to external flame or intervention of external flame, this external flame will come in contact with the shell of the vessel, this external flame will weaken the vessel, it reduces the vessel strength to hold liquid or gas at higher temperature.

(Refer Slide Time: 43:18)



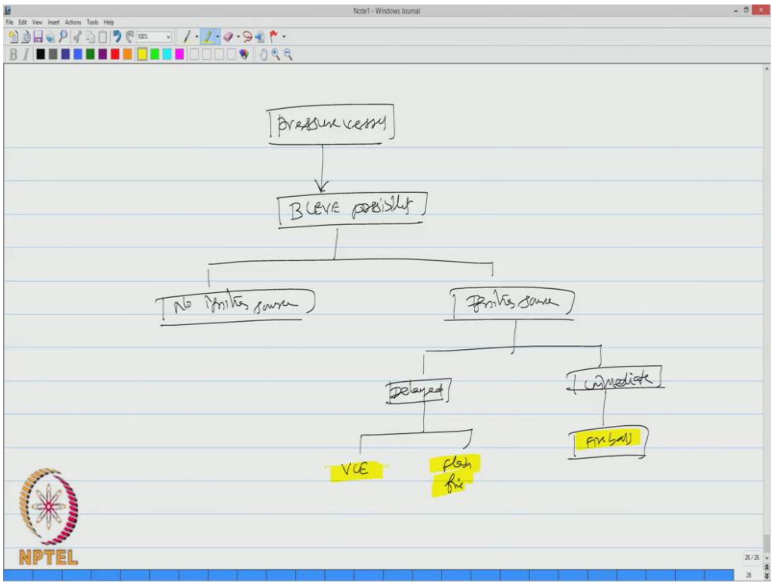
Let us see the consequences of the sudden release of energy in steps. So, let us see steps in terms of consequences, first step could be containment of the sealed vessel is exposed suddenly due to accident as a result of which internal pressure raises rapidly; vapor is generated wall temperature of the vessel increases, result of which wall strength decreases rapidly. Pressure relief valve failed to operate we are looking at the consequences as a result of which the container ruptures and the super heated liquid is released finally.

(Refer Slide Time: 45:16)



On release it expands vaporizes and therefore, causes catastrophic damage to the vessel, it also spreads ignited vapor for a long distance.

(Refer Slide Time: 45:56)



If you look at the flow chart of failure of pressure vessel, we can say pressure vessel will have a BLEVE possibility, we have already seen how and when BLEVE can occur.

Now, once the BLEVE occurs there are two possibilities; there is no ignition source and there is presence of ignition source. In the presence of ignition source you can again have two sub classifications; ignition is delayed, ignition is immediate. If it is delayed it will result in vapor cloud explosion and flash fire, if it is immediate it will result in formation of fire ball. So, all these consequences of vapor cloud explosion of flash fire, formation of fire ball are quite catastrophic in nature which can cause serious deterioration to the material as well as to the member or the plant under consideration.

So friends, in this lecture we started explaining the characteristics of explosion, glossary of terms involved in explosion, types of explosion and we are slightly understanding their application of explosion in design of pressure vessels or safety assessment of pressure vessels, which are quite common (Refer Time: 47:53) present in topside of any offshore platform like semi submersibles drilling rigs etcetera.

Thank you.