Health, Safety and Environmental Management in Offshore and Petroleum Engineering

Prof. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

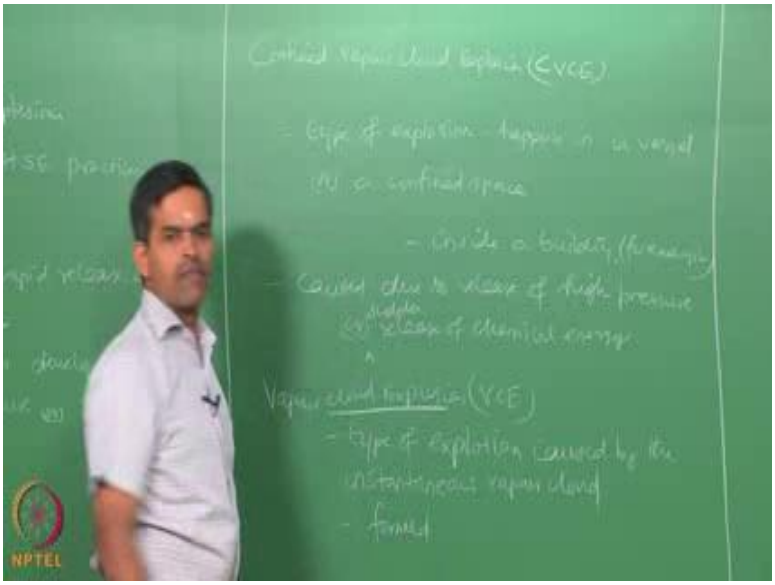
Module – 03
Accident modeling, risk assessment and management
Lecture – 04
Explosions

Welcome friends to the 4th lecture where we will focus on explosions.

(Refer Slide Time: 00:18)

So, lecture 4 we will focus on explosions which is in module 3 of HSE Practices, which is under the brace of NPTEL; IIT, Madras. Now, first let us ask a question, what do we mean by explosions? Explosion is actually is a rapid release of energy which causes development of pressure or shock waves. Let us talk about confined vapor cloud explosion.

(Refer Slide Time: 01:41)

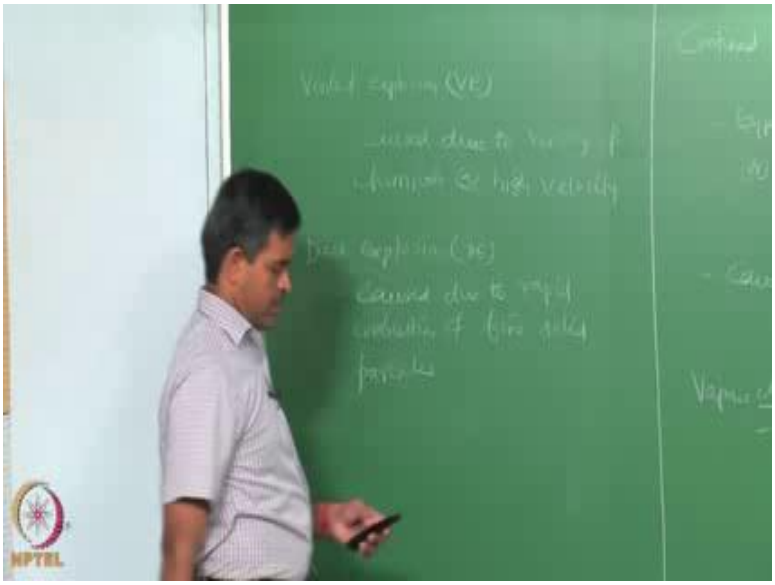


Confined vapor cloud explosion which is actually type of explosion that happens in a vessel or a confined space may be inside a building, for example, it is generally caused due to release of high pressure or release of chemical energy. You can even say sudden release of chemical energy. The next could be simply vapor cloud explosion which we call as VCE, this again is a type of explosion caused by the instantaneous vapor cloud. This vapor cloud is generally formed in air due to release of chemicals into atmosphere.

(Refer Slide Time: 04:16)

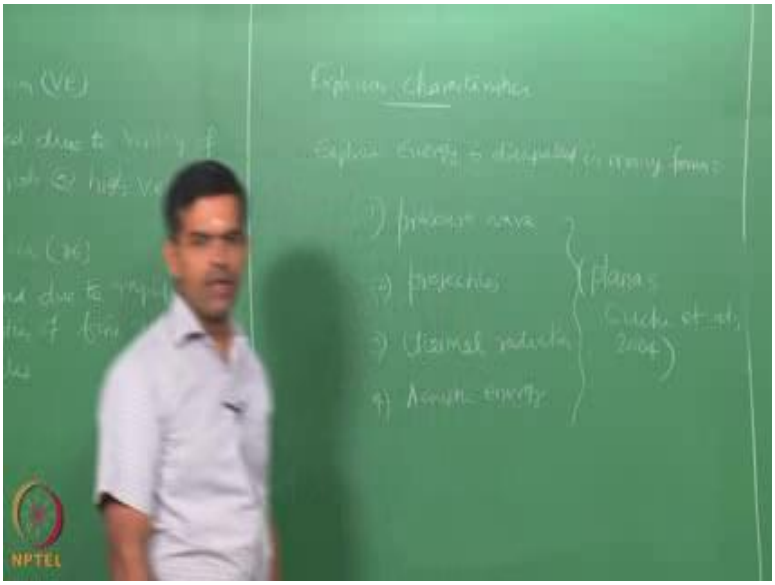
The next could be boiling liquid expanding vapor cloud explosion, what we say as BLEVE; Boiling Liquid Expanding Vapor Explosion. There is no cloud here, BLEVE is actually caused due to instantaneous release of large amount of vapor; instantaneous mean sudden release of large amount of vapor through narrow opening that is very important. So, essentially it is caused at high pressure. So, it happens generally under pressurized conditions which is one of the serious effect or serious consequence of accidents are said by Tasneem Abbasi and Abbasi, 2007.

(Refer Slide Time: 06:30)



The next could be vented explosion, what we see as VE. This is caused due to the venting of chemicals at high velocity. The next could be dust explosion; DE, this is caused due to rapid combustion of fine solid particles. We already saw the flammability characteristics of a given mixture in the last couple of lectures.

(Refer Slide Time: 07:54)

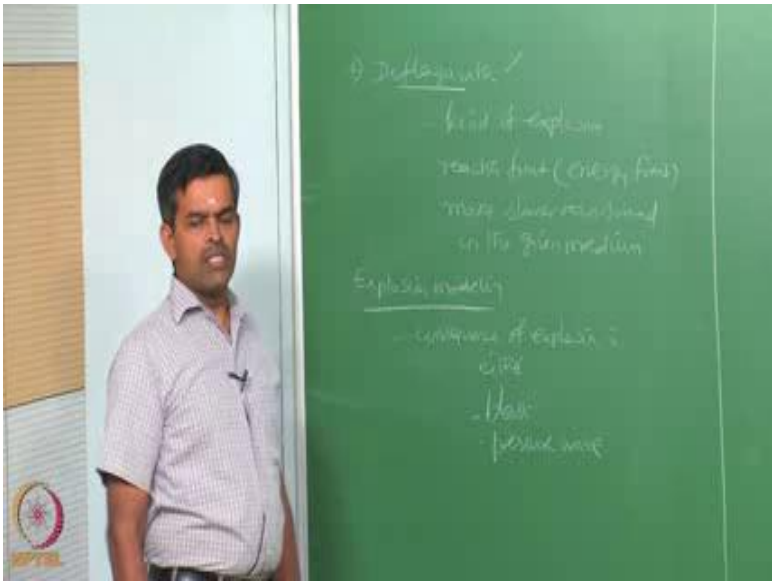


Let us talk about explosion characteristics; explosion energy is actually discipline in different forms when a chemical or any mixture explodes. The explosion energy is actually dissipated in many forms. It can be a pressure wave, it can be in the form of projectile, it can be also in the form of thermal radiation, it can be also in the form of acoustic energy as said by Planas Cuchi et al 2004. We will discuss some of them in details. Now, let us see what is a blast wave?

(Refer Slide Time: 09:19)

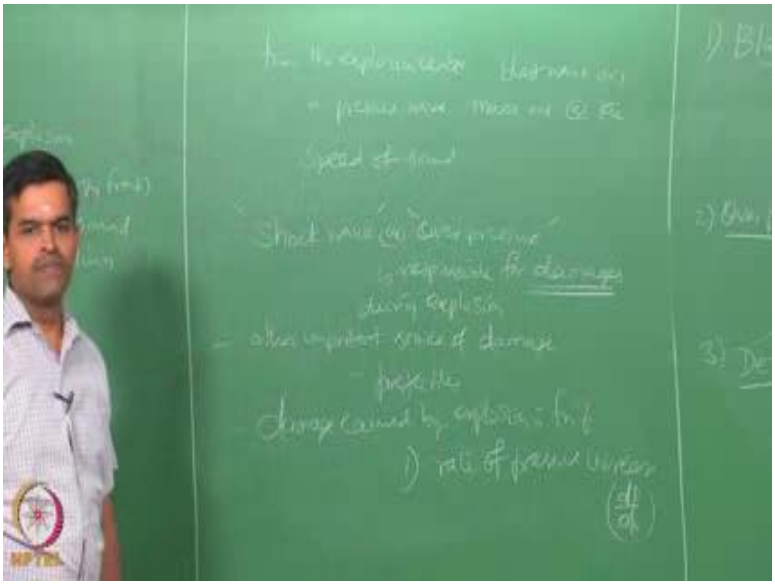
Blast wave actually is a shock wave in open and it is generally followed a strong wind. So, the propagation is very faster. The second could be over pressure, it is actually the effect caused on any object by impacting shock wave. The third could be interestingly detonation, actually detonation is the kind of explosion where the reaction front moves ahead that is at a greater speed with respect to sound in a given media.

(Refer Slide Time: 11:24)



The next could be deflagration; deflagration is again a kind of explosion in which the reaction front that is nothing, but the energy front moves at a lesser speed than sound in the given medium. So, one of the classical differences between the detonation and deflagration is the time taken by these two explosions or these waves pressure, waves to reach the specific point or this spread on the specific destination because this moves ahead sound, this actually follows the sound. The sound is faster than this, in this case. Considering these one is interested to do the explosion model. We all know that explosion results in a blast or a pressure wave. So, the consequence of explosion is either of blast or a pressure wave which moves out from the explosion center at the speed of sound.

(Refer Slide Time: 13:19)



So, from the explosion center we have blast wave or a pressure wave moves at the speed of sound. Now, shock wave or over pressure shock wave or over pressure is actually the basic cause for damages during explosion are responsible for damages during explosion. So, one is interested to actually know the explosion modeling. The objective should be to estimate the consequences or the effects caused by explosion, one is not actually interested the chemical reaction which results in explosion, one is interested to know if explosion occurs what would be the consequences because we are talking about risk estimate of this risk management essentially or let us say programming for safety. In either case, one is interested to know the effects caused by explosion.

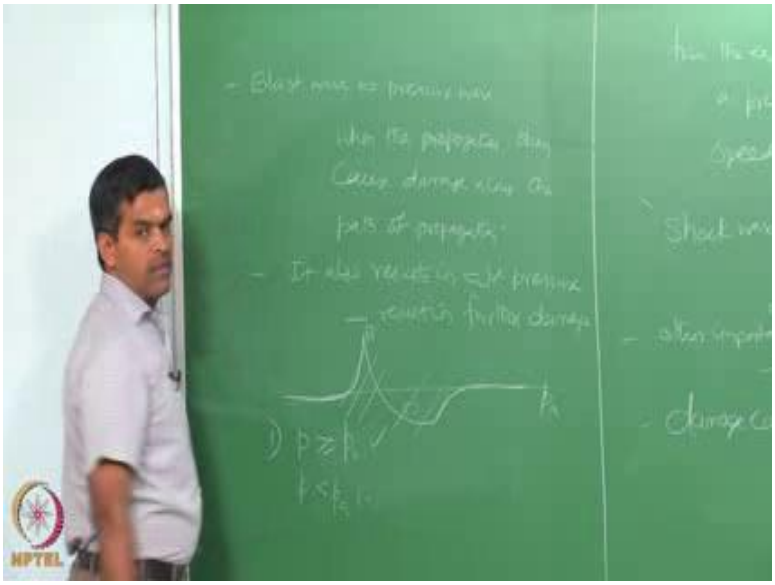
So, one is actually interested to know how damages can be caused by explosion, essentially the shock wave or the over pressure are responsible for causing damages during explosion. So, one is interested to know how to compute the damage cost either by a shock wave or over pressure that is what we will now further see. The other important source of damage could be also the projectiles which also get released from the explosion center, but generally the damage caused by explosions is actually a function of rate of pressure increase and duration of the blast wave. So, one can say the damage caused by explosion is a function of the rate of pressure increase. Let us say d p by d t rate of pressure increase and duration of the blast wave as we all understand. Now,

there explosion generates a rapid raise in pressure whether it is one of the important effects of explosion.

(Refer Slide Time: 16:44)

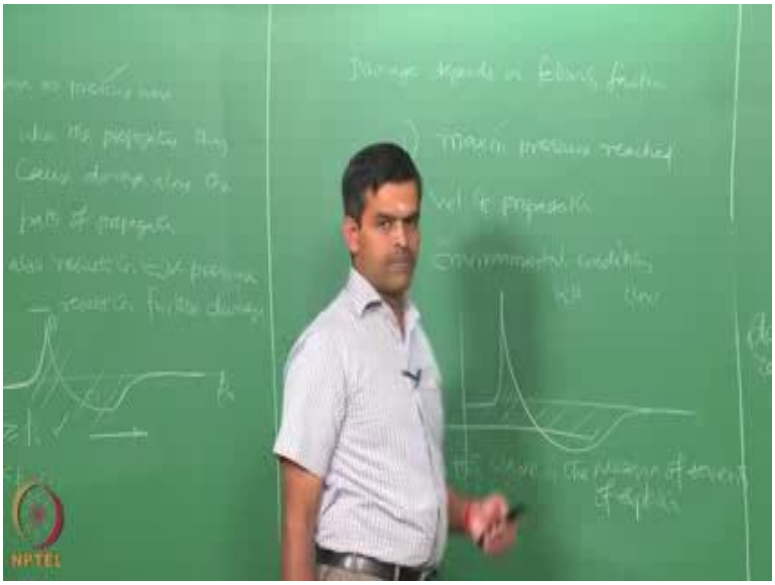
The important effect of explosion is a rapid rise in pressure; is steep rise in pressure. Therefore, the damage caused by explosion is essentially based on the peak side of over pressure. It means where the peak of over pressure occurs, when the peak of over pressure occurs, what time if I able to estimate this then one can easily find out the damage caused by explosion, this can be computed. Interestingly, the propagating wave may be the blast wave or the pressure wave.

(Refer Slide Time: 18:17)



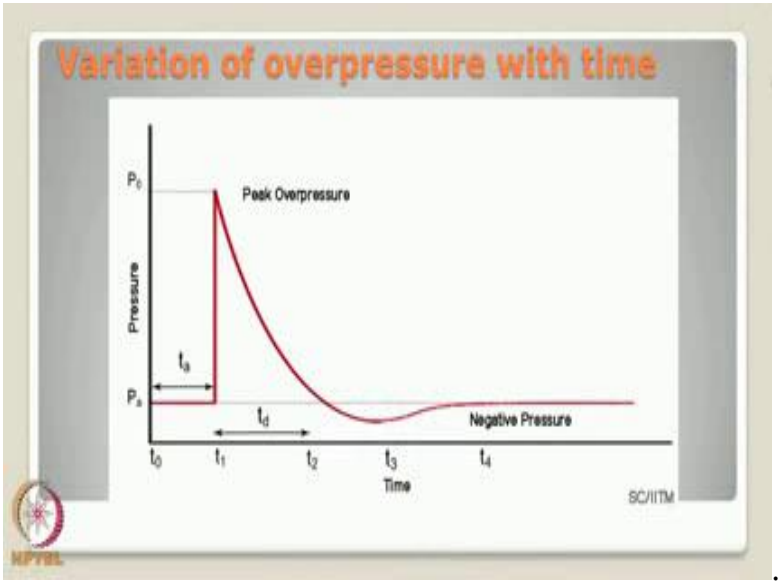
When it propagates they cause damage along the path of its propagation. Sometimes, it also results in negative pressure. Therefore, the cause of negative pressure will result in further damage before the pressure returns back to the atmospheric pressure because pressure wave peaks up goes to p 0 then comes down and then brings, this is the negative pressure. So, this has damage in two stages; one the first damage occurring when the pressure reaches or exceeds the over pressure the peak value, damages occur. Secondly, when the pressure goes below atmospheric that is negative pressure then also damage occurs. So, damage occur in two stages; one at this stage one at this stage this happens or long the direction of propagation or the path of propagation either of a blast wave on of a pressure wave, which are the consequences of explosion damage. Now, the question comes what are those factors which contribute to damage.

(Refer Slide Time: 20:21)



So, let us say damage depends on the following factors; one it could be based on the maximum pressure reached. It also depends on the velocity of propagation. It of course, depends on environmental conditions. Interestingly, let us quickly see how the over pressure whereas, it time please by attention to the curve shown on the screen now.

(Refer Slide Time: 21:15)



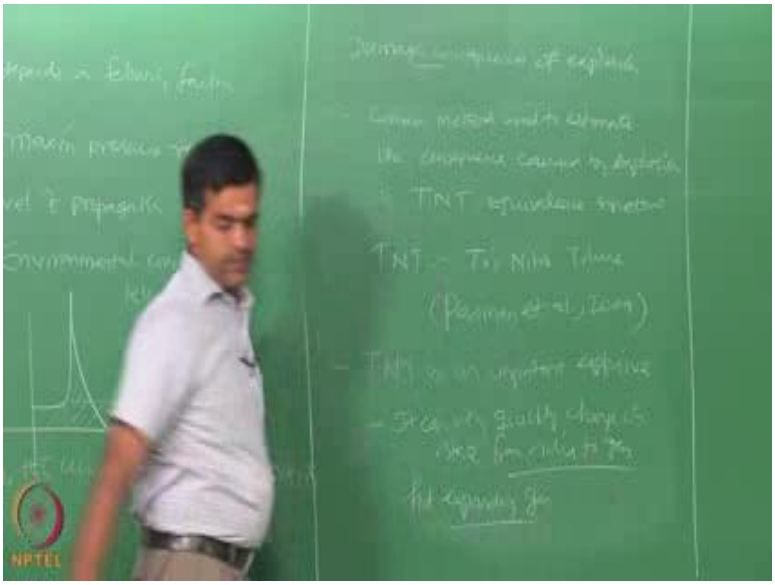
This shows the variation of over pressure with time the y-axis plots the pressure from the varying range from atmosphere the over pressure. So, suffix over stands for over pressure and ‘a’ stands for atmosphere equation the x-axis plots time where different indices of t 1, t 2, t 3, etcetera are indicated qualitatively and this x-axis, when the pressure is atmospheric because of the explosion occurrence the pressure peaks up instantaneously because you know explosion is a sudden release. So, instantaneous release of energy which causes high pressure, the pressure which is instantaneously the over pressure or peak over pressure, time acquire or let us say the time delay caused in reaching the p 0 is what we call as t a, which is the activation time.

Once the over pressure are peak; over pressure is reached. Subsequently, the pressure will fall or decrease will come to atmosphere and goes below atmosphere varies at that point, we call this as degradation time or declaration time of pressure is to called t d. So, it is during this time the damage is maximum. Subsequently, the pressure falls below atmosphere which becomes negative pressure and then before it returns to atmosphere, there is a damage caused to the system maybe human being, dictionary equipments, environmental conditions by tool.

Sectors one is this region of t d at the risk this region. So, the effect of consequence of over pressure on any system is cumulative one from the peak over pressure range other is form the negative pressure range different factors are, what is that magnitude of the maximum pressure, which has been reached of course, depends on velocity of propagation because t a and t d, the time for atmosphere pressure to retain and the declaration pressure to fall down to below atmosphere depends on the velocity of propagation.

Of course, it also depends on the relative humidity, the rainfall, the ultra violet; there is sun ray effect, etcetera. Day and night conditions all depends upon how the peak was pressure actually peaks up from atmosphere and falls down to negative and before it reaches the atmosphere value as we saw in the screen now. Interestingly area under this curve is measure of explosion, area under this curve is the measure of explosion. Let us now see the damage consequences when expression occurs.

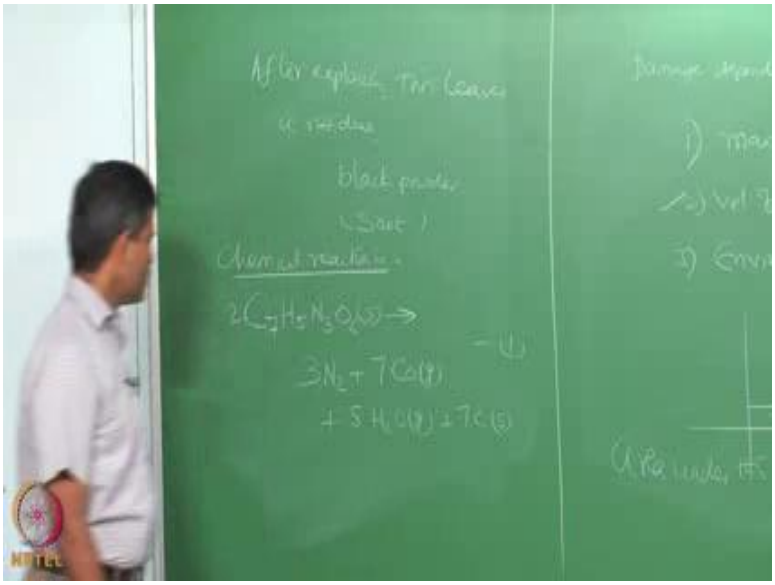
(Refer Slide Time: 24:51)



What are the damage consequences of explosion? One of the most common methods which is use to determine the damage or the consequences arising damage is call TNT method. One of the common methods used to estimate or quantify the consequence caused by explosion is TNT equivalence method. TNT stands for Tri Nitro Tavleen is a very interesting and authentic method to estimate the damage caused by explosion as certify and stated by Pasman et al 2009.

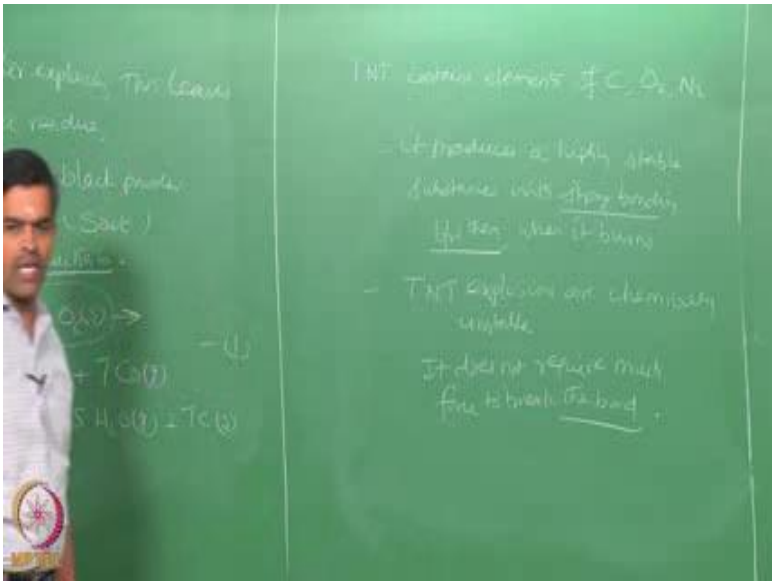
Now, the question comes why TNT? TNT is a very important explosive. We all know that TNT is an important explosive which can cause very severe damage on anybody which is acted upon. It has got a very interesting characteristic; the interesting characteristic is it can very quickly change it state from solid to gas. In fact, hot expanding gas, TNT has got very special characteristic.

(Refer Slide Time: 27:21)



After explosion TNT leaves a residue in the form of black powder which is called soot. Let us quickly see the chemical reaction of TNT, C 7 H 5 N 3 gives me nitrogen carbon monoxide plus of course, the hydraulic compound plus carbon, equation one these actually this is what we call as soot.

(Refer Slide Time: 28:45)



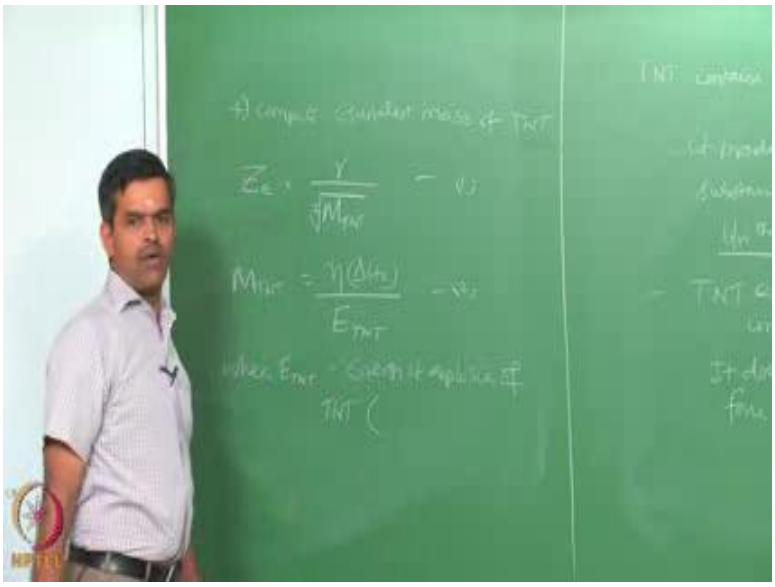
Interestingly, TNT essentially contains elements of carbon, oxygen and nitrogen. It produces a highly stable counter with strong bonding between them when it burns. Interestingly, it has got a very serious characteristic which actually causes worry to all the people who study explosion damages. TNT explosions are chemically unstable, what is it means is it does not require much force to break the bond, which it forms when it is burning, does not require much force, can easily be broken. What we are bothered about is not the effect of TNT on any particular body or any particular material. We are now trying to find out the explosion damage in terms of equivalent TNT. So, TNT is a very interesting chemical on explosive which is commonly used, which can cause very serious disaster because of two reasons; one it can move or expand or change it state from solid to expanding gas very instantaneously within very short duration of time. It lives a black soot powder. It is not a very strong bonding between the three chemicals carbon, oxygen and hydrogen, but; however, it does not require much force to actually break them. So, let us see the TNT equivalents.

(Refer Slide Time: 31:22)

So, I am interested in finding out equivalent mass of TNT to express the explosion damage that is the idea. Step number 1, determine total mass of fuel involved m, mass of the fuel involved. Step number 2, determines energy of explosion required, what we say

delta H c. Now, energy of explosion can be estimated, estimate the energy of explosion which we call as eta, essentially it can be anywhere from 1 to 15 percent.

(Refer Slide Time: 32:57)

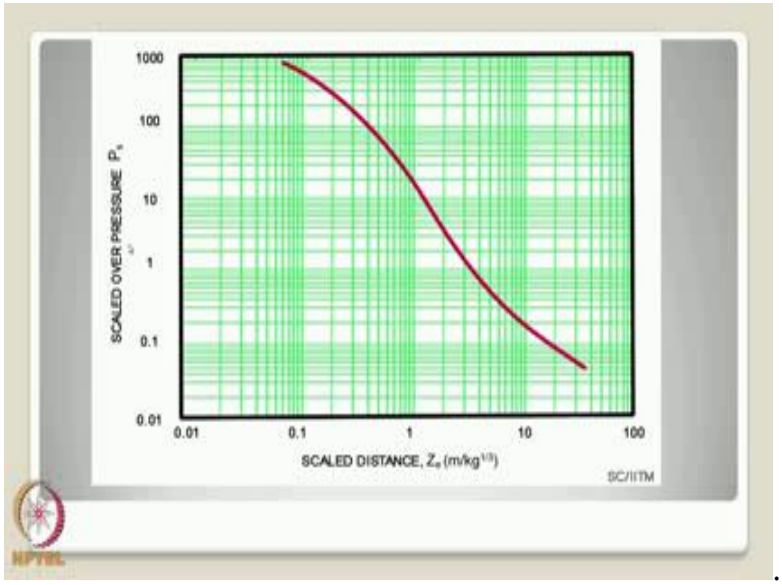


Now, in the fourth step compute equivalent mass of TNT, knowing all the three which can be found out as following Z e will be given by r by the mass of TNT cube root. Whereas, the mass of TNT is efficiency, we can assume it as anywhere from 1 to 15 percent the energy of explosion which is known to us divided by e of TNT, where e of TNT is the energy of explosion of TNT, which is actually equal to 4686 kilo joules per kg.

(Refer Slide Time: 34:34)

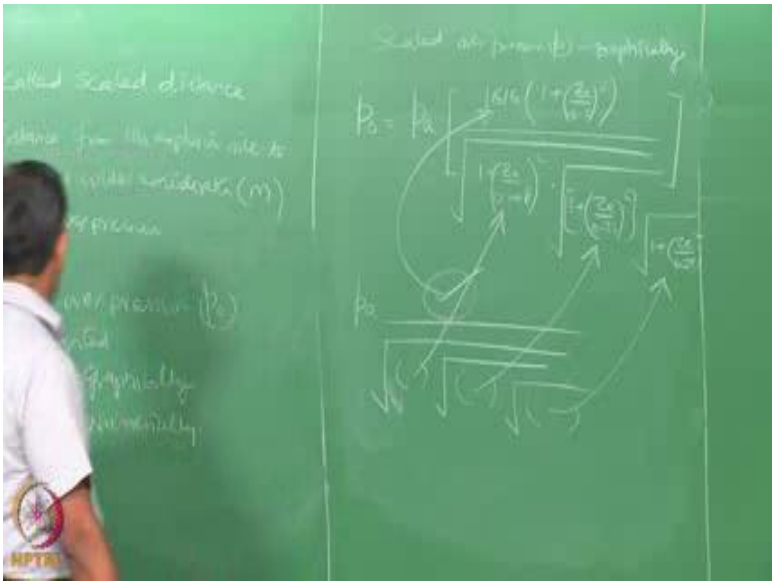
Z e is called the scaled distance. So, once we know the mass of TNT based on the mass of TNT, one can find Z e and r is actually a distance on explosion site to the points of concerned distance from the explosion site to the point under consideration, this will be metric units in meters. So, one can estimate Z e, once we know this equivalent TNT. Now, based on this as we said explosion will cause over pressure or a blast wave. Now, the resulting over pressure which is say p 0 can be computed by two ways; one; we can do it graphically which I show you. Two; one can also do it numerically which I will give you the equations. Please be attention to the figure show on this screen now.

(Refer Slide Time: 36:39)



If you know the scale, it distance ready using this log curve one can estimate what is called scaled the work pressure graphically.

(Refer Slide Time: 36:43)



So, one can estimate the scaled over pressure graphically to the data given to on the screen. Now, one can also calculate from this equation, if you know the atmospheric

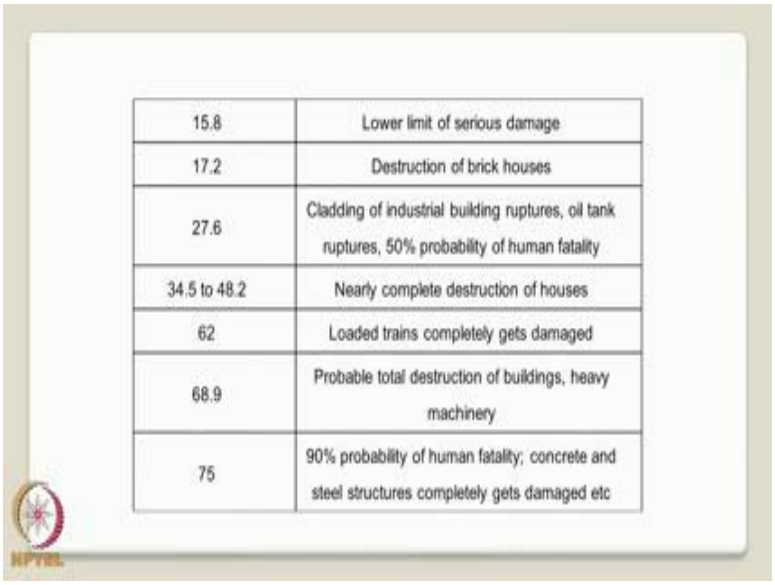
pressure and 16 1 plus Z e by 4.5 square divided by square route of 1 plus Z e by 0.048 square into square route of further 1 plus Z e by 0.32 square and further square route of 1 plus Z e by 1.35 square. So, essentially it is p a, times of some numerator square root of some value multiplied by square route of some value multiply square route of, this value is this, this value is this, this value is this, this numerator is this.

So, one can graphically or numerically estimate over pressure, but still we are interested in knowing the damage from the equivalency of TNT. Once, you know the over pressure, one can directly relate this over pressure to the damage. Please look at the comparative show shown in the screen.

(Refer Slide Time: 39:09)

Explosion damages caused by over pressure, if we know the over pressure in kilo pascal compared to damage or relative damage can be estimated for 0.28, it is going to be a glass failure which will result in 143 decibels. Whereas, from 6.9 to 13.8 is going to even cause significant damage to wooden and asbestos and so on.

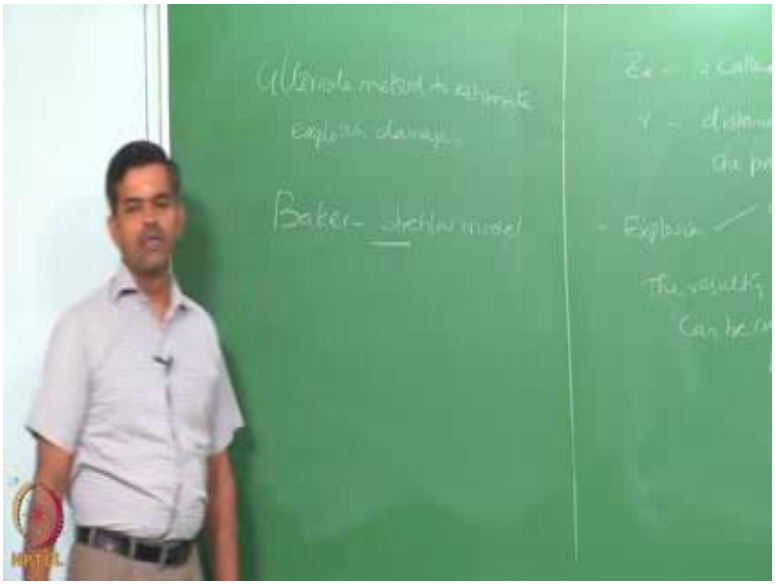
(Refer Slide Time: 39:33)



Further more if the damage over pressure exceeds close to 75 results in 90 percent probability of human fatality, even concrete and steel structures will get completely damaged. So, what we are trying to do in this exercise, we are trying to compare the damage cost by TNT in terms of equivalency trying to get TNT equivalence mass of TNT equivalence participating in the damage depending upon, what is the efficiency of explosion and what is the delta x e value for a given mixture.

Once you know this scaled distance, if you know the distance at which you want to measure the damage from that of the distance from the explosion site, the news graphical technique or algebraic equation given to you, you calculate the peak over pressure. If we know the peak over pressure comparing it with the table shown to you, just know one can estimate the equal relative damage caused this, how we estimate explosion damage in the literature alternate methods are also available in the literature one equivalent method it is also very popular.

(Refer Slide Time: 40:58)



The alternate method to estimate explosion damage is Baker-Sheblow method. So, friends in this lecture we understood, how to actually do the explosion modeling in risk assessment; one is actually interested to know the damage or the consequence or the effect caused by explosion. Explosion is a process which results in adequate release of energy which happens instantaneously, the pressure will rise from atmosphere to peak over pressure instantaneously within a very short duration of time, then it degrades or falls the pressure below atmospheric before returns back to the atmospheric normal. So, the damage caused by explosion is cumulative effect between these two stages of peak over pressure retention and during the negative pressure of time.

So, one is interested know the damage in terms of relative values. So, TNT equivalents technique is a very interesting and popular method as advised by Pascal, etcetera in the literature. So, TNT has got special characteristic which makes it a very powerful explosive. So, people use equivalent TNT method to compute the peak over pressure as expressed to you in the lecture. Alternatively, one can also look at other models to find out the explosion damages.

Thank you very much.