Introduction to Explosions and Explosion Safety

Prof. K. Ramamurthi
Department of Mechanical Engineering.
Indian Institute of Technology Madras

Lecture - 38
Atmospheric Dispersion

Good Morning. In today's class we first do something like 3 illustrative examples on atmospheric dispersion. So, that we can follow it in the context of explosion and safety and once that's over we get into quantification of damages. Let us, see you know lets starts with an example.

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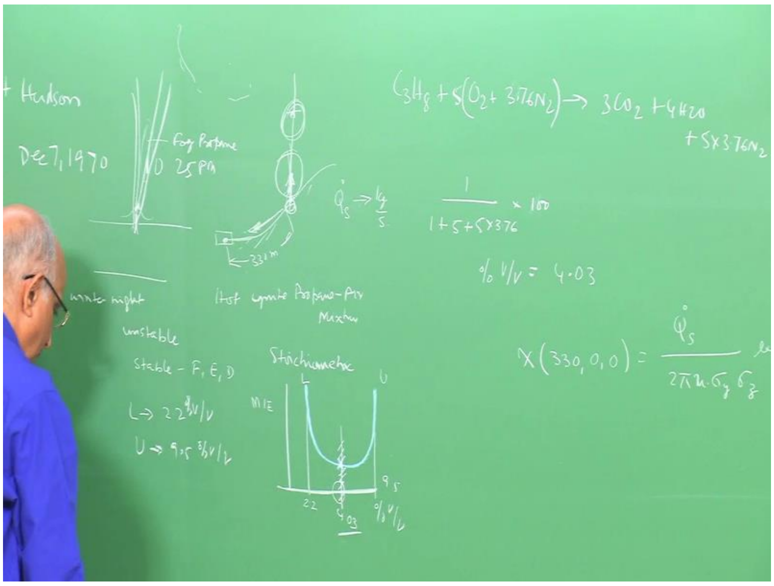

Let's take the example of the explosion at Port Hudson in Missouri, you know this happened we said on something like, December 7, 1970 at night around 10 25 pm night. You know being December being the cold month it was extremely cold that evening or that night. And what happened in this incident is you have a pipeline conveying liquid Propane which sort of burst the Propane was on high pressure a r around 65 bars.

It open that 1 of the welding joints and you had a huge fountain of liquid Propane and liquid Propane is when at a high pressure it stored as a liquid. And this is as the ambient temperature, but at the ambient pressure of 1 atmosphere it boils that something like minus 43 degree centigrade and therefore, it immediately flashes into wafer.

That fleshing into wafer absorbs the and you have a Fog of Propane wafer, which is found in addition to the Fog of the Propane wafer it also entrance some air. And therefore, you have a something like a mixture of Propane air which is being formed at the zone where in the burst takes place. We had also told our self earlier, that this particular pipeline was on the side of a hill and this and there were not much many buildings around it.

But at a placing a downwind, that particular day the wind at night was around 2.7 meter per second wind. And the wind was down hill and at a place something like 330 meters away, after something like almost some 10 15 minutes. The Propane air mixture that is the propane, which is gushing out gets drifted by the wind in the atmosphere it and it keeps getting look at that the dispersion of it and it enters into a warehouse.

In the warehouse what happened is, if hoist has some refrigeration unit and some of the hot motors or the control motors of the refrigeration unit ignite the Propane air mixture. Now, we want to look at the dispersion of Propane downhill along the wind and 2 things we realize: 1 is it is the night time. They are also told that, the sky is fairly cleared which means, we said the cloud covered above this particular area that is a cloud that is available is something on the low side.

The temperatures are around minus 1 to 0 degrees centigrade cold night. Therefore, we have something like in the atmosphere you have atmospheric inversion; that means, positive temperature gradients above the surface. And we looked at atmosphere in terms of its unstability; unstable atmosphere wherein anything gets dispersed away on a cold night where in the atmosphere is stable. You could have extremely stable atmosphere, you could have some at moderately stable, you could have something, which is very weakly stable.

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PASQUILL'S CLASSIFICATION OF ATMOSPHERIC STABILITY

Surface Wind (m/s)	Insolation			Night	
	Strong	Moderate	Slight	Overcast with cloud cover > 1/2	Cloud cover <3/8
<2	A	A–B	B	E	F
2–3	A–B	B	C	E	F
3–5	B	B–C	C	D	E
5–6	C	C–D	D	D	D
>6	C	D	D	D	D

And therefore, let us look at this qualification I show it in slide over here. We are talking of wind speed of the order of 2 to 3 that is around 2.7 meters per second, we are talking of a night wherein the cloud cover is very small therefore, the classification of the atmospheric stability is F therefore, and we recognize therefore we tell that well. The condition of atmosphere that that night where in the leak is happened is F point 1, point 2.

You know the type of ignition energy is which are hot source like, something like a hot compressor or a control unit of refrigeration can give is quite small. Therefore, we expect may be the Propane air mixture which got found, which got drifted and found. In this particular building should have been near to stoichiometric. Why it should be near to stoichiometric?

Let us take say if I consider a propane; Propane has a lean flammability limit around let us say 2.2 volume by volume, percentage volume of Propane and a volume of mixture, upper around 9.5 to 10 percentage volume by volume and in between those 2 if I write from plot. Let us, say the minimum ignition energy verses I say percentage volume by volume, well this correspondence to something like 2 to 2.2 to 2.2 to 2.5 this is a lean limit of flammability; upper limit of flammability well.

The curve for the Ignatius energy would be minimum ignition energy would be minimum around stoichiometry and it will go up over here. Therefore, let us see what is the type of stoichiometry mixture, which should have found here otherwise, it could not have ignited. Because we do not have good igniter around the strong igniter and therefore, let’s work it out.

Let us, say for Propane air mixture I am talking of Propane C3H8 plus oxygen 1 mole of oxygen in air carries 3.76 moles of nitrogen and for stoichiometry I found completely burned product of combination I have 3 carbons. Therefore, I have 3 Co2 and have 8H items gives me 4 H2O and the 4 the Oxygen which I need to carry this 3 plus 2 that is 5. And accordingly I have 3.76 into 5 moles of Nitrogen I get in my products I have 5 into 3.76 moles of Nitrogen.

Therefore, what is the type of mixture which should be formed such that it is going to be stoichiometric? Well it is going to be 1 volume of Propane divided by 1 plus 5 plus 5 into 3.76 moles of Nitrogen. This is the total volume of the mixture or rather, when I talk in terms of percentage volume by volume is going to be into 100 and this correspondence to a value around 4.03.

Or rather if I write to put in terms of this may be I am looking at this around let us, say 2.2 to 2.3 I am looking at the l value around 9.5 apparently I should have found a mixture. In the warehouse, where in the ignition prime really happened after something like almost 15 minutes after release of gas, after the release got started over here. I should have found a mixture over here, which is around 4.03.

Now, I want to calculate what is the dispersion, what is the value of the concentration at this point, when some maths gets realized here. Let us, say the maths which is released in this cloud is something like let us say Q dot s this is abbreviation we are working. You know, what happens is the pine line leaks for quite some time a therefore, you form this fountain this fountain exists for some time.

Therefore, this frog is something like a continuous release over a period of time. And therefore, I can assume it to be a steady heat release so much kilograms per second.

Therefore, two things we say namely at the warehouse I should have formed a mixture whose volume by volume percentage wise volume of the Propane is divided by volume of mixture is 4.031 second is. We also say that the atmospheric stability conditions on this particular day, when they accident happen or when the leak happened is condition F. Therefore, lets come back yes I have the atmospheric condition being F and therefore, let us say how I should do this problem.

Therefore, I tell well I am interested in the concentration at a distance we say this distance downhill is 330 meters and it is downhill along the wind. Therefore, I am looking at concentration 330 I am not looking at the lateral direction it's along the direction of the wind. Therefore, y is equal to 0 on the surface of the earth that is 0 and this we found is equal to Q dot s divided by I have 2 pie u into the dispersion coefficient in the y direction.

Dispersion coefficient in the easier direction and we if we have a spill of something like it was between let us, say 15 to 25 meters something the spill of the particular height. I take the mean height of the spill is something over here at from which the gas defuses out. I say well it is equal to exponential of minus the height at which the effective Maths gets released that is h square divided by 2 sigma is its square.

This is the way I get the concentration, but before I get the concentration let us do physically let us, try to understand the problem little bit more before I use this particular formula. The first what is it I do I may be the lines have been some concentration, as the spill takes place.

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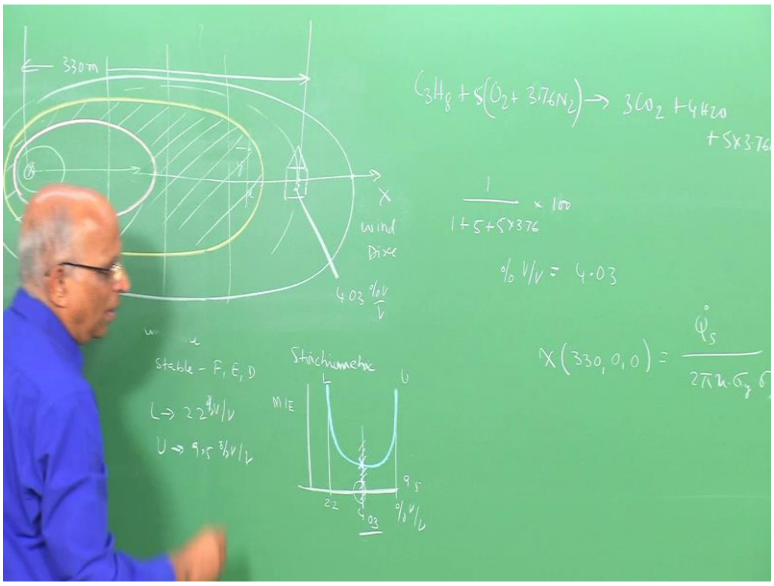

Let me, say well the spill takes place over here; corresponding to the place where the pipeline leak occurred. After sometime well the spills out over here that means, this is the direction of the wind; wind direction along this still after sometime in a little bit over here it and well comes over here this is the way the spills out. And after sometime well the spill further and so on may be after quite sometime well spill keeps propagating out.

Because, the wind carries that forward this is the direction of the wind let's say x that is the direction of the wind direction. Well this is at the lateral direction you have the maximum concentration over here and along the lateral 1 I can do that. If I do the lateral the concentration may be at this particular point all what I say is, at this particular station x where in I get this value of sigma y and sigma z.

At this particular point I know introduce the value of exponential minus y square by 2 2 sigma y square I can therefore, determine at any concentration. Therefore, I can determine may be when the front of the particular cloud along this is here well. I know that the concentration in this zone is so much may be when the cloud travels forward the concentration in this and this is what I want to do.

In this is where may be the warehouses and this is where is get the stoichiometry value of the mixture as being 4.03 percentage volume by volume and this is what I want to calculate. And this distance we say, is from the source is something like 330 meters and this is what is given in the problem.

Therefore, to be able to get I am going to calculate the concentration may be at this particular point or may be at this particular point going over here. And the lateral wants if I am interested in some mixture over here in some particular flame over here. We know well the flame got formed over here; the damages of this building are just a few meters compared to 330 meters.

Therefore, I am just looking at the value of concentration and this without any we are not looking at the lateral dimensions and therefore, this is the type of concentration I am looking at. Therefore, I have to determine the dispersion coefficient sigma over n sigma is it. We also note this atmospheric stability is in an open area, there are not many buildings apparently there are some trees.

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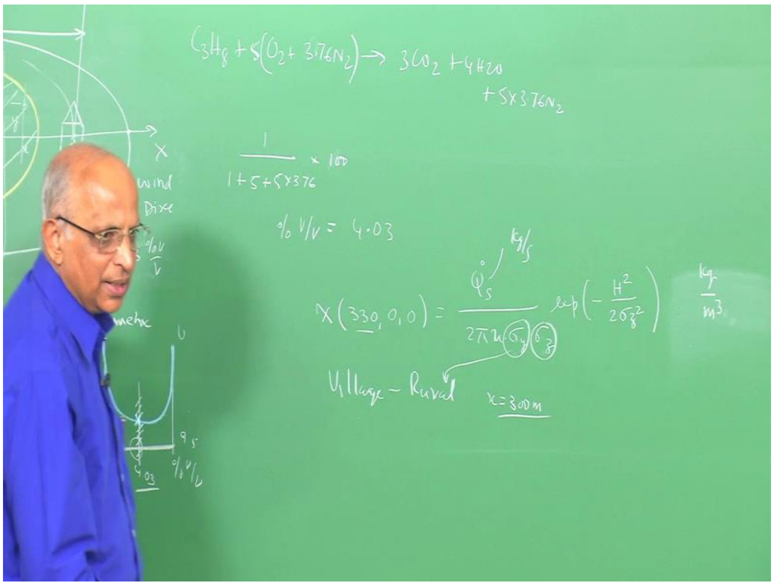

Therefore, it is as good as in a village where in you do not have the high raised building which creates descend all that. Therefore, I say well I need something like a rural surrounding rural area therefore, the value of sigma y and sigma z at 330 meter away for which I want to calculate should correspond to a rural condition and not an urban condition and the study to lease so much kilo grams per second. Therefore, I will get the concentration in kilo gram per meter cube right. Therefore, we have to look at the rural for the dispersion coefficient and therefore, let us take a look at the dispersion coefficient and get the values of sigma x and sigma y.

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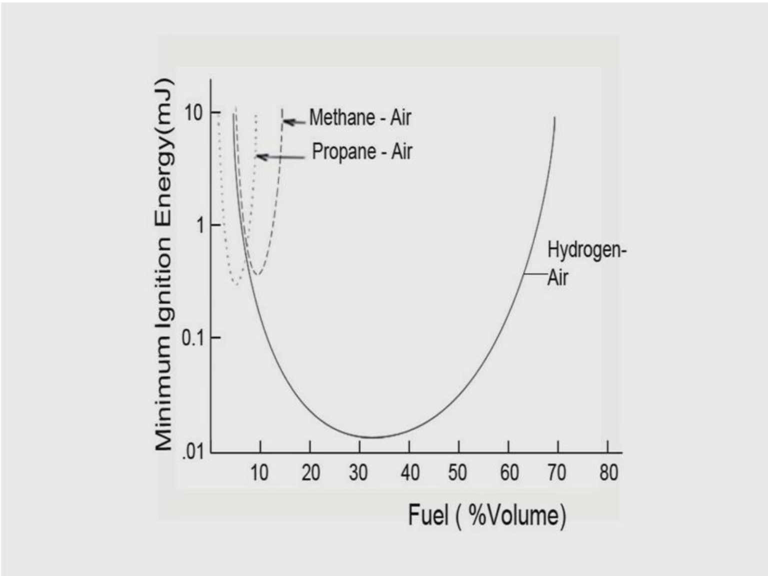

Therefore, we go for the we say that these are the minimum ignition energy as a per percentage of volume of fuel divided by the volume of mixer. We find well Propane air has a very narrow range and the upper range was 9.5 and the lower range was around 2.2 well the stoichiometric around 4. And when we talk of Methane well; my Methane has a lower value of the has a yes higher value of the percentage fuel in the volume of the mixture.

But its value of the upper value u value is much higher and if we talk of Hydrogen, well it's even wider we do problem involving Hydrogen shortly. But you know, this is the type and this is what we are talking of as stoichiometric and I want to calculate the value at 330 meters and I want to find out whether stoichiometry mixture is possible.

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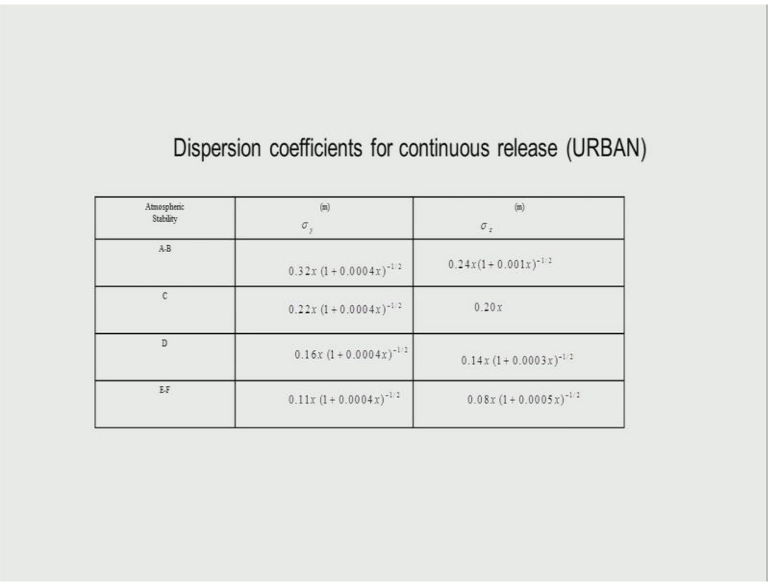

Dispersion coefficients for continuous release (URBAN)

Atmospheric Stability	(m) σ_y	(m) σ_z
A-B	$0.32x\,(1+0.0004x)^{-1/2}$	$0.24x(1+0.001x)^{-1/2}$
C	$0.22x\,(1+0.0004x)^{-1/2}$	$0.20x$
D	$0.16x\,(1+0.0004x)^{-1/2}$	$0.14x\,(1+0.0003x)^{-1/2}$
E-F	$0.11x\,(1+0.0004x)^{-1/2}$	$0.08x\,(1+0.0005x)^{-1/2}$

Well we go to the next 1 we look at the dispersion coefficients for continuous release in urban. We said such formula and figure available both as plots and formula.

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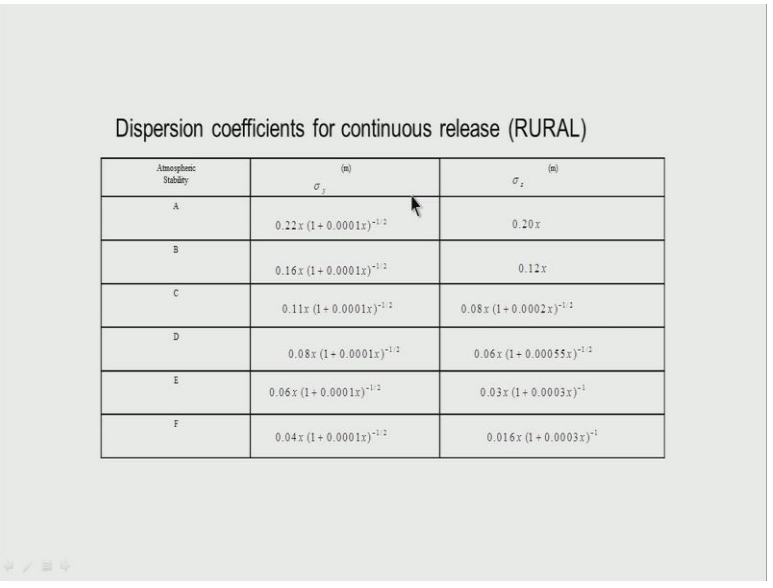

Dispersion coefficients for continuous release (RURAL)

Atmospheric Stability	(m) σ_y	(m) σ_z
A	$0.22x\,(1+0.0001x)^{-1/2}$	$0.20x$
B	$0.16x\,(1+0.0001x)^{-1/2}$	$0.12x$
C	$0.11x\,(1+0.0001x)^{-1/2}$	$0.08x\,(1+0.0002x)^{-1/2}$
D	$0.08x\,(1+0.0001x)^{-1/2}$	$0.06x\,(1+0.00055x)^{-1/2}$
E	$0.06x\,(1+0.0001x)^{-1/2}$	$0.03x\,(1+0.0003x)^{-1}$
F	$0.04x\,(1+0.0001x)^{-1/2}$	$0.016x\,(1+0.0003x)^{-1}$

We are not interested in urban; we are more interested in rural. Because, there are no big buildings and are also said well just now, that the atmospheric stability condition A B C

D E F being a cold winter night. The wind velocity being quite low at 2.7 meters per second and not much cloud covered. The dispersion coefficients sigma y is given by this equation, sigma z is given by this equation let calculate these values.

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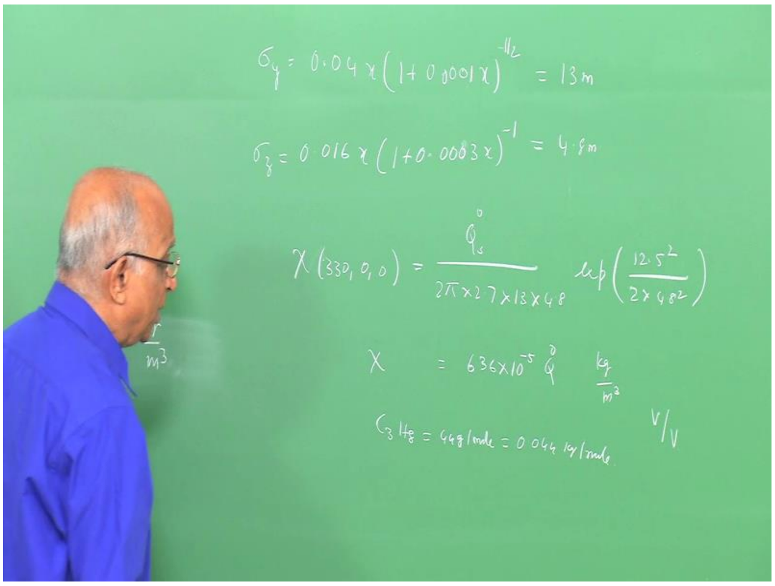

Therefore, I now get sigma y is equal to 0.04 x into 1 plus 0.0001x to the power minus half, where x is the 330 meters. And you get sigma z is equal to 0.016 of x into 1 plus 0.00030 x this is 3 0s 30 into 3x to the power minus 1. If I substitute the value of x because, I am interested from the point a distance 330 meters.

The value of sigma y comes out to be equal to 13 meters that is the dispersion standard deviation which is the dispersion coefficient. The value of sigma z comes out be 4.8 meters therefore, I am interested in the concentration at 330 meters away y is 0; that means, I am not looking in the lateral. I am just looking along the window direction on the surface of the earth z is equal to 0 gives me the value as q dot s divided by 2 pie wind velocity 2.7 meters per second into sigma y as 13 sigma z as 4.8 into exponential of.

Now, we know the mean height of the fountain from which it is coming let us take it as 12.5 meters 12.5 square into 2 into sigma is its square that is 4.8 square. And if I solve for this I get the value as equal to 6.36 into 10 to the power minus 5 Q dot s, where Q dot s is kilo gram per second and the value of at this particular point is equal to kilogram per meter cube.

Now, I would like to convert the concentration kilogram per meter cube into volume of fuel or volume of Propane divided by the volume of the mixture. And immediately I note well Propane has a formula C3H8 therefore, twelfth is the 12 3 the 36 plus 8 44 gram per mole is the molecular maths or rather this is equal to 0.044 kilo gram per mole. And we know, a mole of any substance has a volume at a standard condition of 22.4 liters here the temperature is something like 0 degree centigrade.

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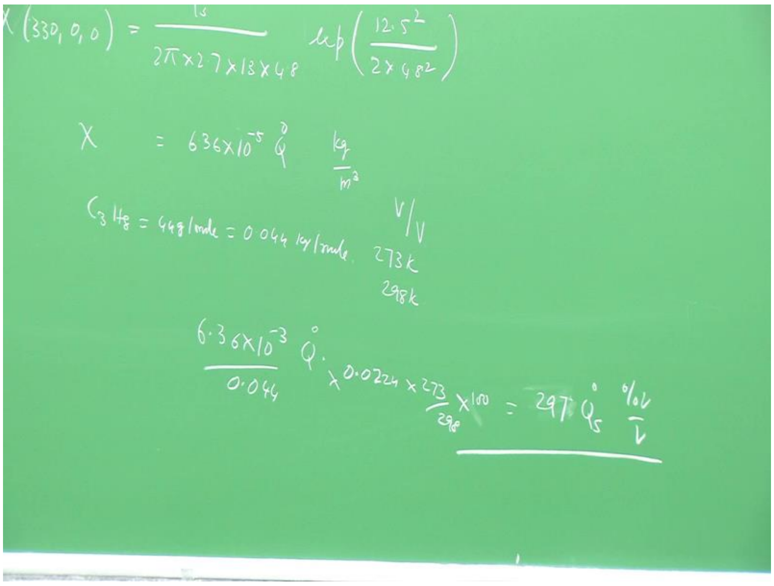

Temperature is 273 Kelvin instead of being standard condition being 298 Kelvin. Therefore, if I aware to express in terms of volume by volume I get is equal to 6.36 into 10 to the power minus 3 into cube dot into now. This is so much kilo gram in terms of mole it is 0.044 and now, this is so much moles a mole of gas contains 22.4 liters that is 0.0224 meter cube per meter cube.

I correct for the temperature is equal to 273 divided by 298 this gives me so much volume by volume and if I want percentage volume by volume is multiplied by 100. And I get the value of concentration in percentage volume of Propane, by volume has equal to into Q dot s so much kilo gram per second into 100 that is 297 so much percentage volume by volume.

Therefore, I find I am able to find out at this particular distance this and if it is going to be something like 0 is equal to something like 4.03 corresponding to stoichiometry. I can estimate what is the rate of the leak or if I know the rate of the leak if it is given to me Q dot s well I can find out the concentration here. And I can verify whether the stoichiometry mixture is found at what distance may be at this distance a stoichiometry mixture would have been found.

Therefore, such type of problems we do to estimate the effect of atmosphere in dispersing the gases. Therefore, you know in such problems we are able to take care of the different conditions of the atmosphere like: a cold winter night, the wind condition, the cloud covered.

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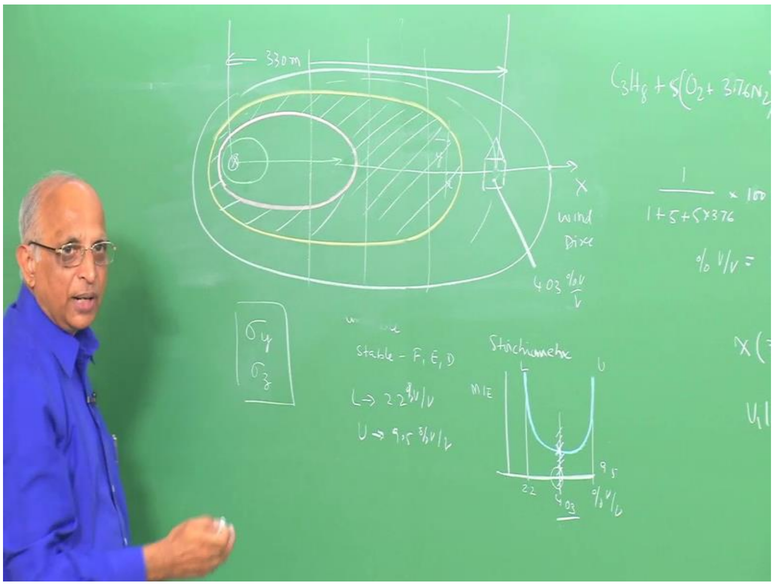

And solve it using the determined parameters of the dispersion coefficient of sigma y and sigma z, which are calculated for the particular Atmospheric conditions. Well this is how we do problems on atmospheric dispersion and this is how the problem of the case of the Port Hudson leak is done. Let us, take 1 more example and this example is important because, you know it is happened in Bhopal and we call it as a Bhopal gas tragedy.

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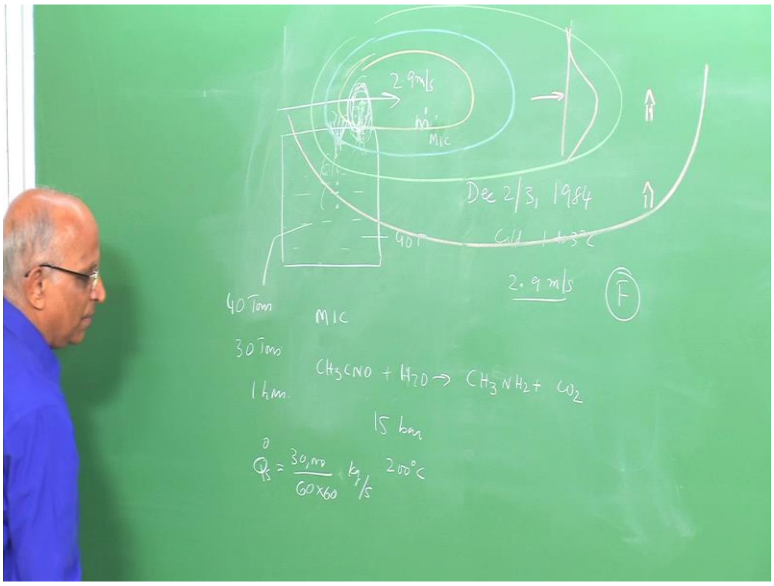

You had a tank containing Methly isocyanate gas, isocyanides liquid, Methly isocyanate. We have huge quantity something like 40 tons of Methyl isocyanides and what happened during the regular cleaning operations and remind you, the plant was not doing well there was not much incentive for people to work here. One of the workers while cleaning the wells you know, he there should have been a hood which protects the in grace of water into the Methly isocyanides while cleaning it.

He did not apparently take the precautions and water sort of sip into the Methly isocyanate; that means, you have Hydrolysis of the Methodized cyanide, Methodized cyanide is CH3 CNO and it reacts with water in the Hydrolysis reaction. That is water and what it forms is CH3 NH2 Methylamine plus it also forms CO2. Therefore, the act of accidental in grace of water into the Methodized cyanide tank let to generation of Carbon dioxide which is gas increases the pressure.

This reaction is therefore, increases the temperature and also you know, there were other problems you know the tank was not cleaned containing little bit of Chloroform, little bit of Iron. And therefore, temperature start building up well you have the sort of this

Monomethyl mean here may be it further reacted this with the Methodized cyanide to form let us say Diethylurea and it further reacted with ah Mythologized cyanide to form and so on.

But this is the primary reaction, well the tank pressure got increased to something like called almost 50 bar and the temperature because of the increased something like 200 degree centigrade. Therefore, it is bubbling over here bubbling and hot the gas something like when you shake a soda bottle you have the mixture of water and air that is the 2 face flow coming out because of this bubbling over here.

The liquid and the gaseous Methodized cyanide get released through a and we know, we already told the if only gas flow takes place; the rate of math's flow through the went small. But the movement you have liquid and gas; that means, 2 face flow through went well. Because, evaporation of the liquid over here it generates a much larger quantity of the wafer of the gas which is wended out. And therefore, you have a large amount of Methodizes cyanide.

Methly isocyanide, which is coming out of the tank in the Bhopal gas tragedy; well if the accident happen that is get backed to atmospheric dispersion on the night almost midnight 2 to 3 of 1982 84. I think this is when it happen yes December 2 to 3 1984 it was the cold winter night temperature around minus 1 to temperature around 1 to 3 degree centigrade.

This is the type of temperature; the wind velocity was around 2.9 meters per second which is a very low wind velocity. And this combination of 2.9 meters per second, not a cloudy night either gives you an atmospheric stability condition as a F which is extremely stable. And therefore, well you have the leak taking place over here Methodized cyanide you have the wind velocity of 2.9 meters per second.

And what it does well, just like in the Port Hudson case where in you have the Propane wafer well here of the Metalized cyanide wafer it drags it along in the wind direction something over here; may be with respect to time it drags it even further, may be still further. This is the wind direction this is the particular source and therefore, may be you keep on the concentration of Methodized cyanide.

Primarily troubles along the wind direction, but it also getting defused in the lateral direction. And along the earth you will have may be houses over here, may be houses over here, in which it enters and causes the particular tragedy. Therefore, I am interested let us say well as an example lets calculate the concentration of Methodized cyanide.

Let us, we are not talking of near distances we know you know the fatality in this particular accident are informs calculate at a distance; let say, 3 kilo meters away. Let say, downwind 3 kilo meters away and lets now calculate what is the type of concentration here. To be able to know, the concentration I must know what is the concentration and remind you have something like out of this tank, in which had something like 40 tons of Methodized cyanide.

Something like 30 tons leaked out, in a matter of something like an hour therefore, if Q dot s is equal to 30000 divided by 60 into 60 so much kilo kilograms per second is what leaked out. I know the value of Q dot s and I want to calculate the concentration at a distance let us say 3 kilometers away.

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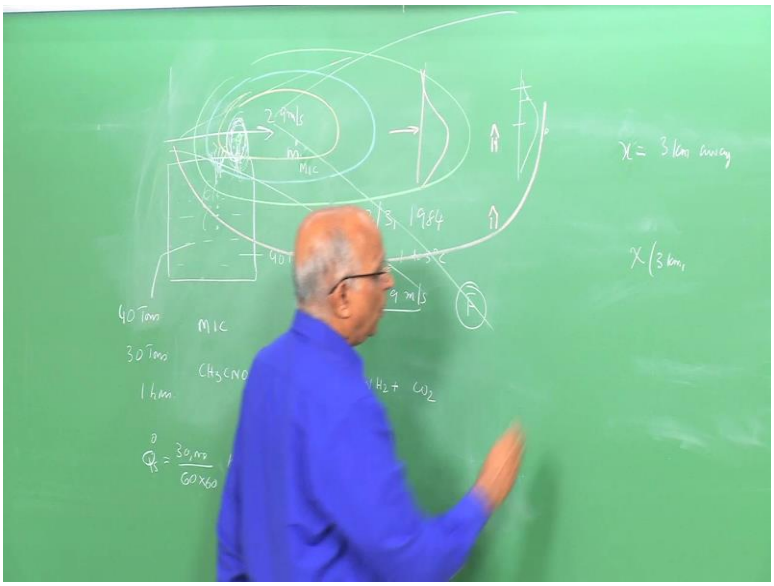

Therefore I say well, concentration at 3 kilometers let us calculate the mean value. Because, once I know the mean value I can always apply e to the power minus y square divided by 2 sigma y calculate the concentration at this at this y. And find out what is the region in which may be the people got affected, may be here also people are getting affected. Therefore, the region increases, the people get affected.

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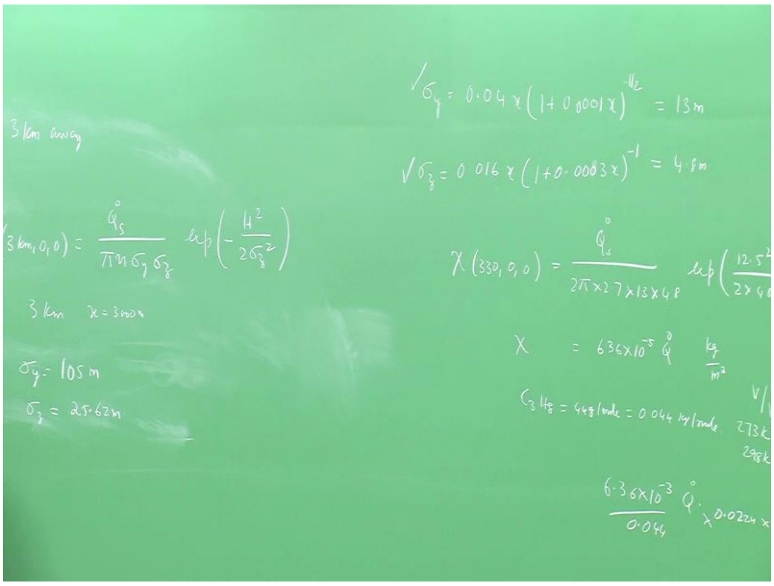

Therefore, at 3 kilo meters away 0 0 I write as equal to Q dot s divided by 2 per divided by pie u into sigma y into sigma z into exponential the height from which the release takes place H square divided by 2 sigma square. Therefore, let us put the numbers down now we put the numbers we say sigma y correspondence to the condition F of the atmosphere.

And that F of the atmosphere yes, we already did the Propane example at atmospheric we know sigma y sigma is a sigma z. Now, instead of using this equation sigma y is equal to 0.4 x into 1 is the 3 meters at x is equal to 330 meters. Now, I am interested in 3 kilometers away therefore, my x is equal to 3000 meters. Therefore, subsisting in the value of x as equal to 3000and 3000 I get sigma y as equal to 105 meters.

You find you know, it is dispersed much more that is that deviation or the standard deviation is much higher. Because, their dispersion is much higher sigma z if I calculate 0.16 x is into 1 plus 0.003 x, where x is equal to 3000. The value is 25.62 meters and therefore, if I where to write the concentration over there, I get concentration at this particular distance is equal to you know, I already calculated 30000 by 60 into 60 this number is equal to 8.33 kilo grams per second.

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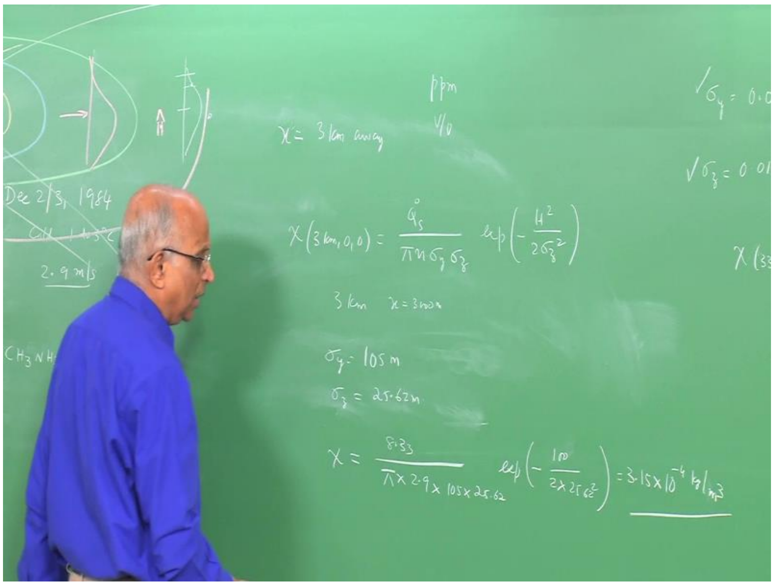

Because, something like 30000 kilograms in a meter of an hour; that means, 60 minutes into 60 seconds 8.3. Therefore, I have 8.3 divided by pie the wind velocity we said is something like that night it was around 2.9 meters per second into the value of sigma y 105 the value of sigma z is 25.62 into exponential of minus the height of the divided by 2 into sigma z square 25.62 square.

You know the height of the stack was around 10 meters and therefore, if I put the height of the stack h square is equal to 10 in to 10 is 100 well. This gives me the value of and this works out to be something like 3.15 into 10 to the power minus 4 kilograms per meter cube well. You know a concentration expressed in kilograms per meter cube is little more difficult to interpret.

Because, we are use to concentration being said as so much sparks per million or volume by volume therefore, lets converted to something like sparks per million. And we do this by looking at the molecular maths of Metalized cyanide, Methly cyanide is CH3 CNO.

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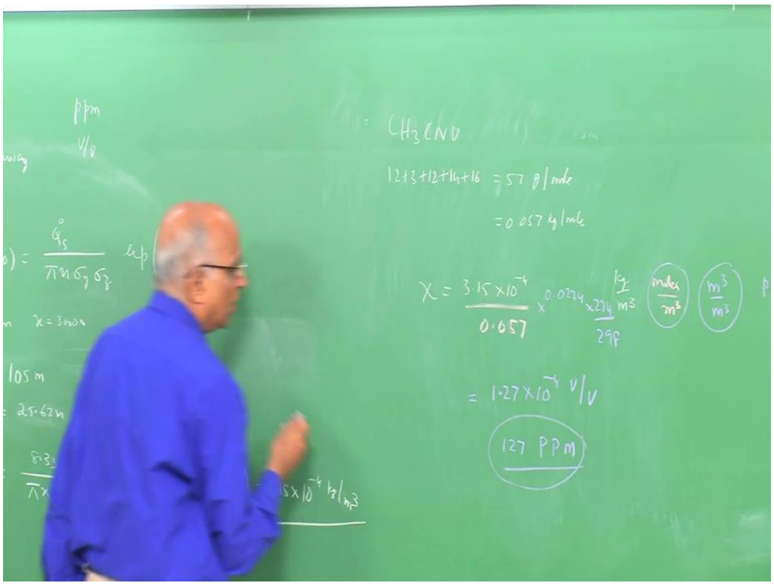

That is 12 plus 3 plus 12 plus Nitrogen 14 plus 16 16 4 30 42 45 45 plus 12 57 C12 CNO 12 24 27 27 41 57 gram per mole. And if I now this is equal to 0.057 kilogram per mole I already calculated the value of concentration as equal to 3.15 into 10 to the power minus 4 so much kilogram per meter cube. I want to convert into first I converted into moles and therefore, I divided by 0.057.

This gives me something like moles per meter cube, I know 1 mole at a standard condition has a volume of 22.4 liters. And therefore, this gives me 0.o 224 so much now this gives me meter cube by meter cube. But this is at the standard condition well that day the temperature was around 2 degrees that is around let say 274 degree Kelvin divided by standard condition 298.

But this gives me meter cube by meter cube got per parts of volume per the total volume. And if I calculate this number, this gives me the number of as equal to 1.27 into 10 to the power minus 4 volume by volume or this is equal to 127 parts per million. Because, million consists of 10 to the power 6 and this is 127; that means, in the air at a distance of 3 kilo meters away.

The Methodized cyanide has a concentration of 127 parts per million, which is quite large and this is the way we look at dispersion of the gas produced in this particular release of gas.

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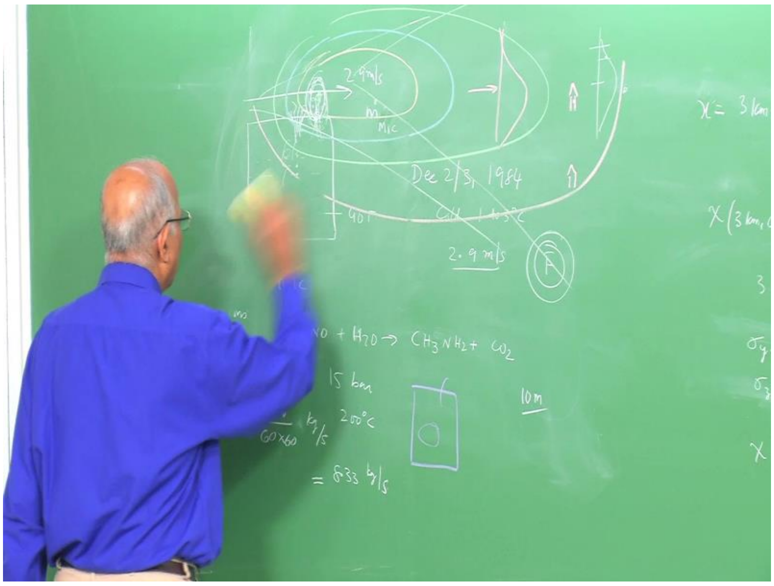

From the wind because of the high pressure due to the chemical reaction. Well this is how we calculate the dispersion let us, do 1 small problem because of late we have the Hydrogen economy, we want to use hydrogen gas, we have seen these gases we did not consider much about their molecular maths. Because, their drifting on the ground let us consider,

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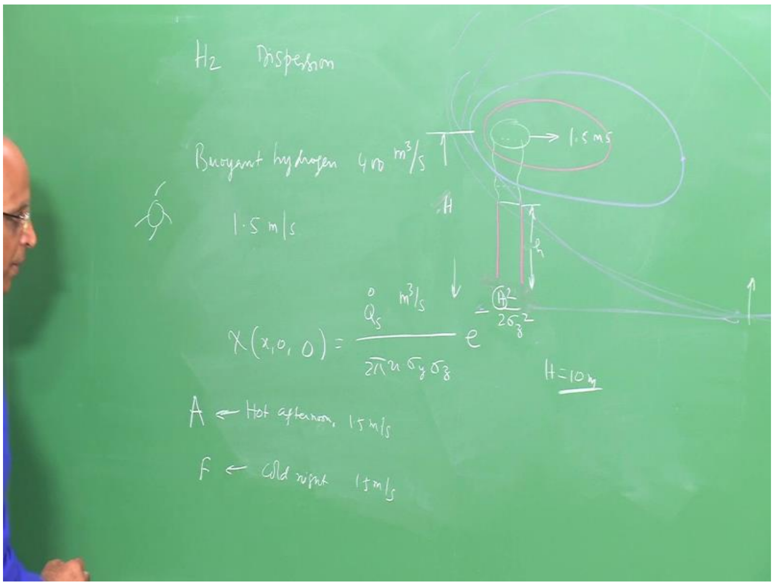

Such as, hydrogen gas and its dispersion well the type of equations what we use the way we do the problems remains the same. Therefore, let us consider the specific example of point Hydrogen being released accidently at the rate of 400 meter cube per second from a stack. You know may be there is a plant which is generating, may be by there is some excess Hydrogen, may be some it is getting released at this particular rate at some instance of time.

Well the wind velocity at on particular day its being released is 1.5 meters per second. Now, I want to be able to say well this is the rate at which let lets draw this figure because, we know to draw the release from stack for a gas well this is the stack. What is going to happen? Because of the initial velocity affects, well the gas will move further and because of the Hydrogen gas being lighter will it comes over here; it mixes with air over here.

So, from here the mix gases; that means, the gases due to the initial velocity and the initial come to this zone over here. The wind velocity takes it forward; at the rate of the wind velocity is being 1.5 meters per second. And what is happens we have a cloud, which is a cloud concentration keeps forming this particular direction and may be it gets it comes at this particular on the ground level it comes here after sometime.

Or at this particular point we know what is the maximum and when its further comes over here it interacts with the earth and then, I can find out the concentration at any point over here. And this is what I want to do and therefore, I again know yes equations are cleared to me now. And well I say concentration at any distance x at may be along the surface of the ground y is equal to 0 along the surface of the ground.

So, that means, z is equal to 0 along the wind direction; that means, along y that is 0 is given by again we have s the maths the volume. Now, I say volume is so much meter cube per second divided by 2 pie u into sigma y into sigma z into e to the power of minus I have the height of the stack into 2 sigma have a you know. In this particular problem let us, assume or based on its density metric or dens metric number I say well that effective height or H even though the height of the chimney or stack from which it is released is h well the effective height from which it is released is H. And we assume that H in this particular problem is let us say, 10 meters well I can find out the value of at the different values of x for the sigma y is so much x for which sigma z I can calculate using.

So, in this particular problem I wanted to do this problem for 2 specific atmospheric conditions: 1 may be the heat the release takes place on a day, when which the wind velocity is small. But it is noon time when I have the sun shining adjust above me, when it is hot afternoon fairly still day when the wind velocity is 1.5 meters per second. I want to do the same problem, when I have cold night the extremely cold again that was not much cloud covered.

Therefore, I say well in the afternoon because of the low wind the atmospheric stability is A cold night not much cloud covered same low wind velocity well it is equal to condition F. Therefore, what is it I do? I evaluate sigma y sigma z at the distance at different distances at the distance of interest and not only at their distance of interest. But also I sort of presume that for condition A I get this value for condition F I get these values.

And I can compare what is the type of concentration I get on non hot afternoon when the insulation is very high or on a cold night when I have a stable atmosphere well. Let us, just quickly puts this down I have the value of F which is concentration is equal to Q dot s I think I already have the formula here no need to rewrite it. I have is equal to Q dot s divided by 2 pie u sigma y sigma z of h square by 2 sigma z square well I am interested in this particular problem at a distance.

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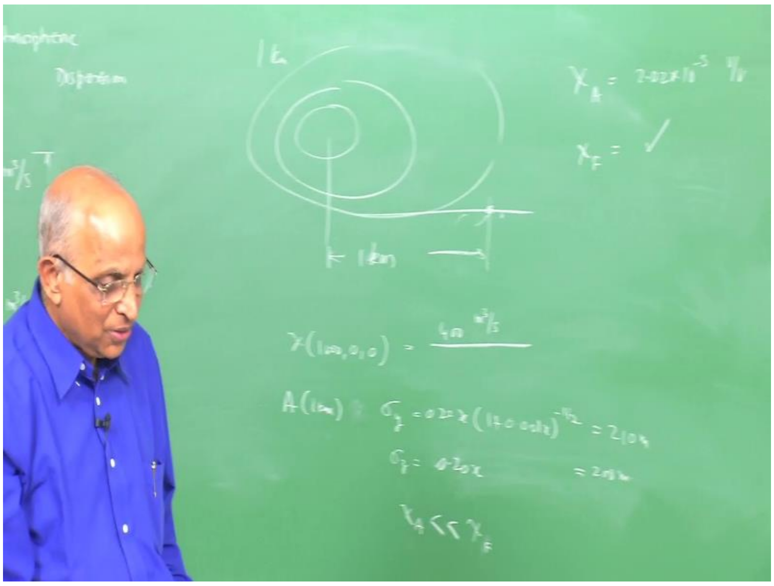

Let us, say 1 kilometer away well it defuses the way; defuses the way, still defuses the way, I am interested to on the surface of the earth at a distance 1 kilometer away at this particular point. Therefore, I sort of calculate the concentration at 1 kilo meter away that is 1000 meters for y is equal to 0 and I am just considering along the wind direction along the surface of the earth.

This mean, a value I am looking at a number wherein i said well Q dot s I gave as equal to 4000 meter cube per second volume is specified. And if I calculate the value at condition A for 1 kilometer I use the formula given for either rural or for urban area. In this problem, be this factory is or this place where the leak happens is again let us say a rural setting.

Therefore, I know the value of let’s say sigma y well sigma y is given by 0.22 x into 1 plus 0.001 x to the power minus half and therefore, and similarly sigma z for condition A is given by 0.03 0.20 x and therefore, you know these are all standard things these are available in at in books on atmospheric dispersion. And I calculate at the value of 1000s meters; the value of sigma y comes out to be equal 210 meters and the value of sigma z comes out to be equal to 200 meters.

Well I substitutes things I know the height of the stack is 10 meters and I can find out the value of for the condition A. Similarly, I know for condition F in the rural setting I know sigma y sigma z I calculate these values and when you do this, you will find that the value of the under atmospheric condition A is very much less than the value under the atmospheric condition. This is F at this condition this is how we do problems involving dispersion of different gases, may be different explosive gases ability to form reactive or a stoichiometry gas mixture.

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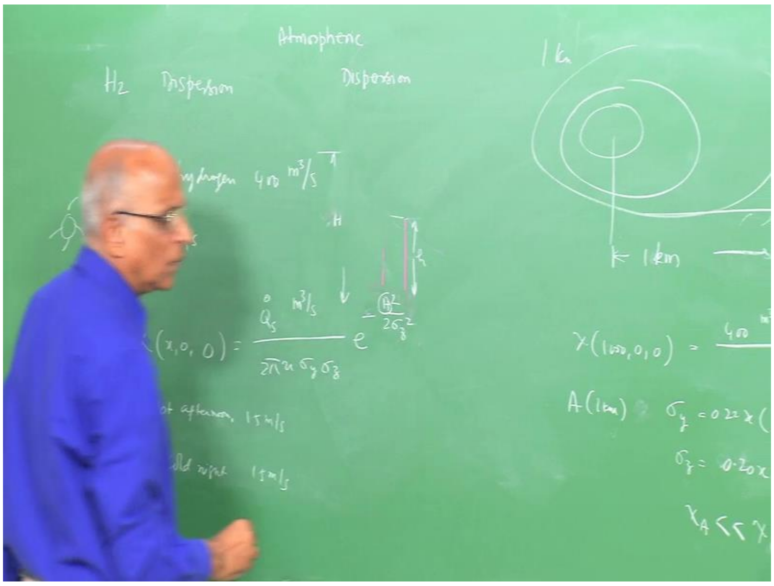

And this is all about the atmospheric dispersion; well we now move forward in we have done so far. We have seen good insight or we have a good insight to different type of explosion we said, well I could say a gas mixture could explore, may be a dust mixture could explore, and the explosion should, would come from atmospheric dispersion.

We also looked at solid and liquid explosives and having said all these we know, but how do we look at the quantification of damages in that is something which we are still to do. Can I say that well this explosion will cause let us say or my lung to get damaged or my house to fall.

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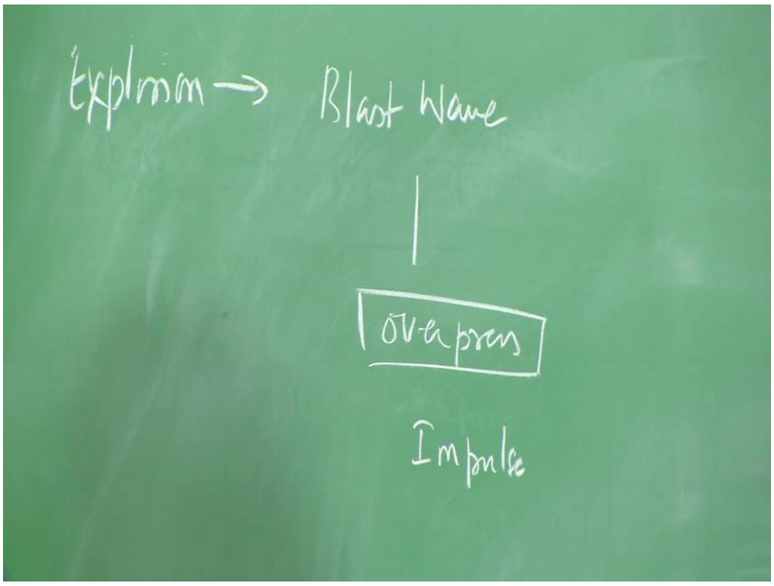

Therefore, let us take an example let us say an explosion takes place and what does the explosion do? well in an explosion you have which have been found and you know even if I do not have blast wave can still be formed. Because, if I have highly trouble and compression I can still get a somewhat weaker blast wave and what does the blast wave do? Well the blast wave has an over pressure across it also has some impulse.

And therefore, let us take 1 look at what are the type of over pressure and what are the type of damages which an over pressure can do. We just take a small particular example and we will not consider all the cases, we just consider what are the damages which can take place.

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QUANTIFICATION OF DAMAGES

- **OVER-PRESSURE**

S. No.	Overpressure Greater than	Consequences
1	0.7 kPa	Window glass panes break
2	34 kPa	Ear drum ruptures
3	55 kPa	Brick buildings get damaged
4	70 kPa	Persons get knocked down
5	210 kPa	Lungs get damaged
6	700 kPa	Lethal for human beings

If I aware to say well over pressure if the over pressure is greater than let us say, around 1 kilo well the glass windows of building will break. If I have over pressure greater than around 35 kilo well ear drum ruptures in a we look at this example we said, well ear drum is a very fast frequency is response and it just ruptures because of the high over pressure.

If I take look at buildings get damaged it happens for around 60 kPa well person get knocked down, when the over pressure that leads him is something greater than 70 kPa. But we also said that, that is not only the over pressure impulse also knocked down the person well our lungs get damaged, when the over pressure is 210 kPa remind you we talked about air in the lungs which causes the implication of reflected blast waves and that is what causes the damage of the lungs.

So, we said if the blast over pressure is greater than around 700 kPa well it is Methly it will also kills human being. Well these are things which are been damages have been cataloged we say well what these things you could get; you could get, the type of the following quantification of damages.

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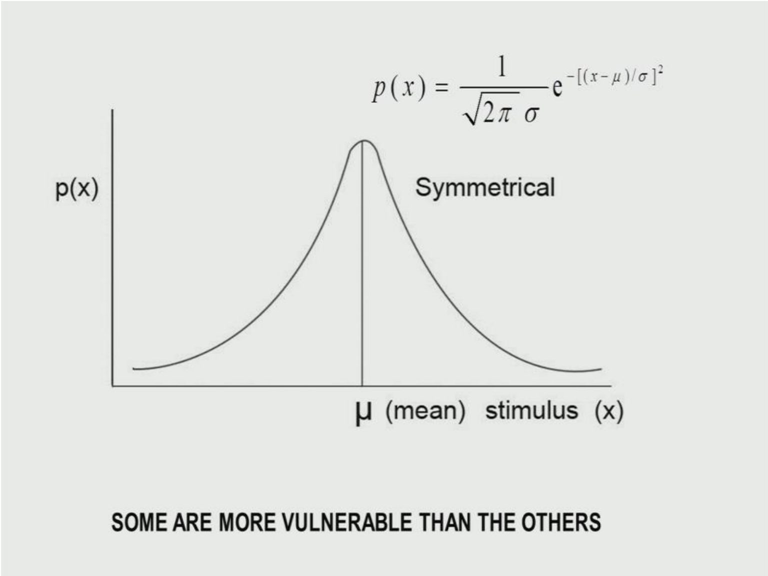

But you know we all know when we talk of damages you know it is not you know may be go back to the previous 1. Well let us, consider the specific case of ear dram rupture may be some people who are very strong and who have better resistance capacity may be even at a 60 kPa is ear dram will not get ruptured; whereas, the small infant child who is more may be it its ear dram would get ruptured at a much lower value.

Therefore, we tell well we know some people or some buildings or some other objects are more vulnerable damage than the others. Therefore, if I have the mean value at which let say damage takes place this is the probability distribution function p x is equal to 1 over by root 2 pie sigma e to the power x minus, where mu is the mean value divided by the standard deviation square.

Even though, the maximum number of people get affected by the average value there are a sizable people who are more vulnerable they get damage, when the over pressure is much lower. And there are some people who are much higher resistance they get can be standup much higher over pressure. And when we say, over pressure causing the damages we will can say well over pressure something like a stimulus which causes this.

Therefore, we say well the it is more reasonable that we represent the effect of over pressure or in this case the stimuli is being over pressure as a distribution like this, where in more number of people or more number of buildings and buildings also have some statistics. Because, the material of construction is not the same there are some dispersion coming over here.

Some buildings have more safer, some buildings have less safer depending on the quality of the material used for construction. Therefore, something like a probability distribution and therefore, we say well we expect that may be that the number of people who get influenced by a stimulus follows a distribution like this.

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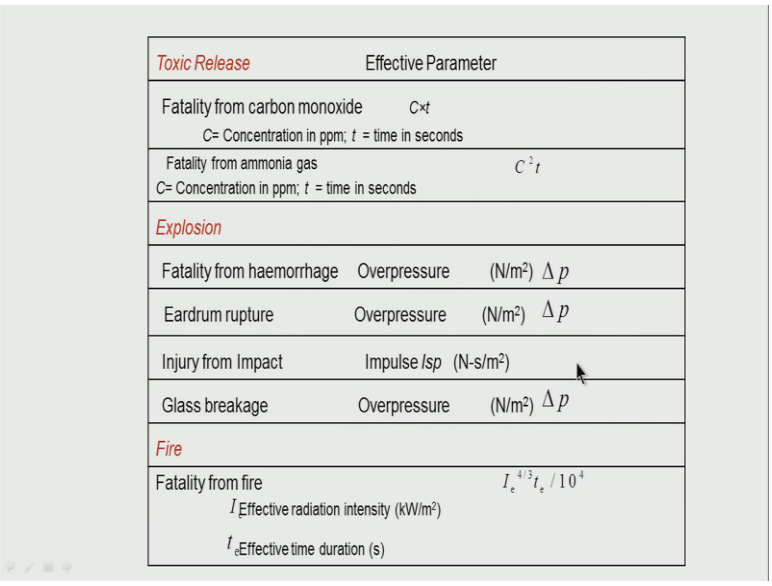

Toxic Release	Effective Parameter
Fatality from carbon monoxide C= Concentration in ppm; t = time in seconds	$C \times t$
Fatality from ammonia gas C= Concentration in ppm; t = time in seconds	$C^2 t$
Explosion	
Fatality from haemorrhage	Overpressure (N/m²) Δp
Eardrum rupture	Overpressure (N/m²) Δp
Injury from Impact	Impulse *Isp* (N-s/m²)
Glass breakage	Overpressure (N/m²) Δp
Fire	
Fatality from fire I_e Effective radiation intensity (kW/m²) t_e Effective time duration (s)	$I_e^{4/3} t_e / 10^4$

This is the distribution having said that, let us go ahead and say what is this stimulus we are talking of I think here I use the minute for I return to the slide.

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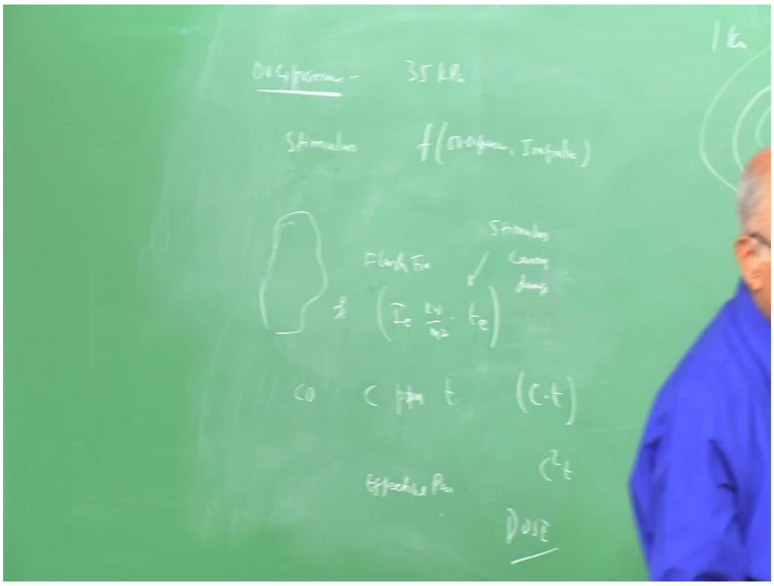

You know when I say over pressure well it is the stimulus, which leads to some ear dram getting ruptured in the over pressure something like 35 kPa and so. But you know what is this you know this stimulus need not be over pressured let me take you through an example suppose, I have cloud of fair which is formed in an explosion suppose you know I have something like a flash fire light say all of a sudden a fire comes and blows out.

So that means, the fire is there hardly for 0 seconds or very very short time in which case may be the people are not affected by the fair whereas, if the fair sustains for a few second well the radiation from the fire is sufficient to calls damages for the human being or to the building adjacent. Therefore, when I take an example of fire the in 10 density of radiation from the fire I call it as AIE so much kilo watt per meter square and also the time over which the fire is available.

That is fire ball is available should be a parameter or that should be the stimulus causing damage. That is the effective parameter causing damage must be a combination of some of let us, take 1 more example supposing I have a spill; that means, in a particular case I am releasing Carbon monoxide the concentration of Carbon monoxide is let us say so much ppm.

If the concentration of ppm is over prolong duration well the effective duration should be concentration into time because, it takes some time for the body to observe the particular poison. And therefore, we say well Carbon we expect a the effective parameter to be may be a product of c and t or, but if you have gases like Ammonia which are much more harmful it could be something like c square t.

Therefore, we have to talk in terms of the effective parameter causing damage which may not be a single parameter like over pressure could be let us say a combination of let us say over pressure. And also impulse in the dynamic region which could be a combination of these parameters and this effective parameter or the parameter or the stimulus which causes the damage is something which is known as a Dose.

Therefore, we tell let lets write 10 to the slide we say that the affect of parameter or doss which causes the particular damage. Then, I have a toxic gas release could be a product of the concentration in ppm into time in second if I have something like Ammonia gas whose concentrate which is a dirty gas you know the concentration is more harmful than the more effective than the time it could be c square t.

In case of explosion if we talk of fatality due to hemorrhage well over pressure is a good index is a single parameter, eardrum rupture we just now saw delta p, injury from impact is more from impulse and what is this impulse? Impulse is a newton second we talk in terms of specific impulse ISP per meter square newton second per meter square we talk in terms of glass breakage again over pressure.

Then, we talk of fatality from let us say fire or a fire ball well you have something like an effective radiation I so much kilo watt per meter square; here the effective time that is effective duration. And it so happen if I do a series of experiments I find that the effective parameter or the Dose which causes the particular consequence is something like Ie to the power 4 by 3 into the effective time divided by 10 to the power 4, where Ie is kilo watt per meter square the effective duration of the fair ball is so much second.

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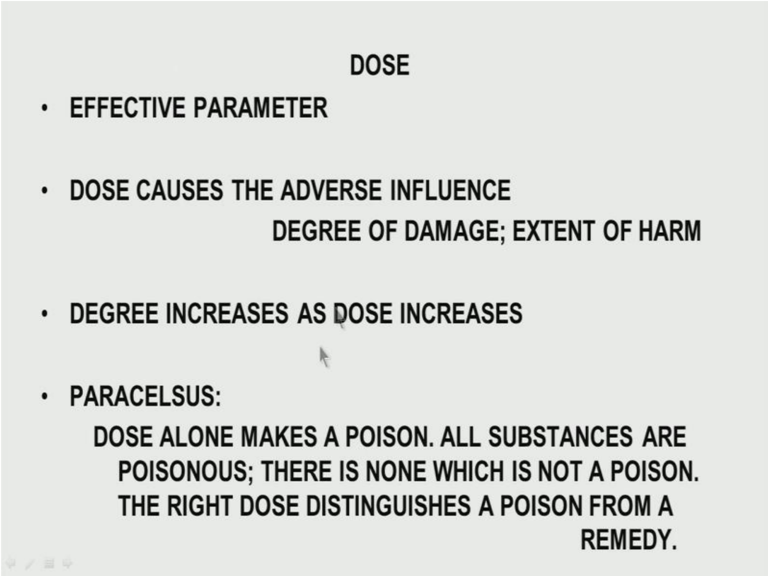

Having said that, well we say well Dose is what we call is an effective parameter the Dose causes the adverse influence like damage, may be death, may be it cause, it can be different as extent of harm. Well as the dosage increases or the effective parameter increase that, the degree of damage which keeps increasing. But you know it is time that we take a look at what exactly Dose does.

You know in sixth century we had a scientist by name Paracelsus and he said Dose alone makes a poison. That is the amount of the effective parameter is what causes the harm all substances are poisonous; that means, he is a everything is poisonous including water. Because, if I drink too much of water well I am in trouble; that means, all substances are poisonous; there is none which is not a poisonous.

The right dose distinguishes a poison from a remedy therefore, we must remember if the dosage is high well I could have the harmful effects coming. And dosage is something like the effective parameter, which causes the particular damage.

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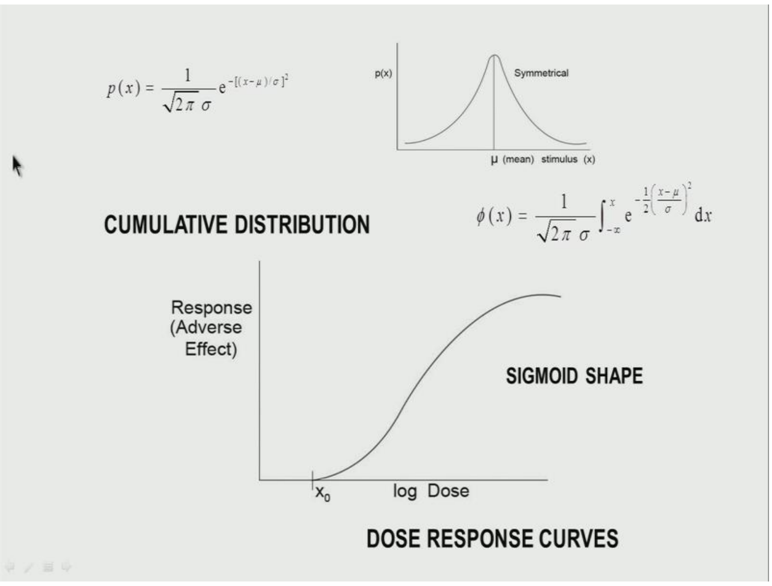

And they already said well if I have a something like a stimulus I could have something like a stimulus, I could have something like a distribution where in the average person gets affected when the stimulus exceeds some limits. But if I were take this distribution and take a cumulative value; that means, I say p x going from minus infinity; that means, I say cumulative distribution phi x is equal to well this becomes the value.

Then, this cumulative distribution has a roll from minus infinity to increase over here well the person starts getting when the dosage exceeds the value x. Because, below this well threshold value is so small nothing really happen therefore, the response or the adverse effect starts over here at a threshold value and keeps on increasing as the dosage increases.

The shape of this curve is a sigmoid shape and such type of curves which tell you the effective parameter how it causes the response or how many people are affected is known as DOSE response curves.

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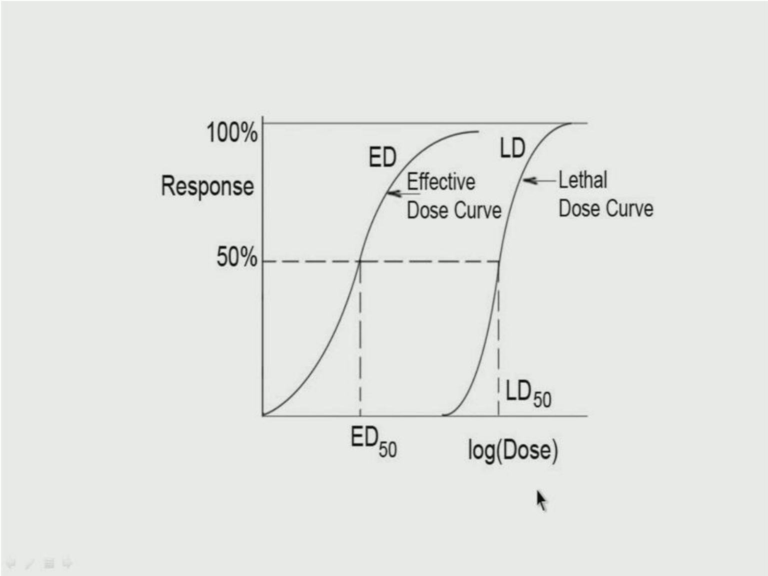

Let us, take a look at 1 last figure; that means, if I have a dosage which causes may be let say human being to be killed we call it as a Lethal Dose may be for dosage exceeding this limit may be people start getting affected. May be an average on an average this is the Lethal Dose may be all types of people all people are apparently killed when the Lethal Dose over here.

This is the cumulative distribution which we said has a cumulative distribution index or something like a sigmoid shape the point where 50 percent of the objects or 50 percent of the people are affected is known as Lethal Dose 50 is known as LD 50. So, also may be it this is for Lethal Dose, maybe I could have an injury which people can recover we say is reversible when it is a reversible we say Effective Dose.

Effective Dose will be less than the Lethal Dose well; I have a cumulative distribution like this when 50 percent of the subject get affected I say well it is a Effective Dose or ED 50. In between the Effective Dose and Lethal Dose I could have something like let us say Toxic Dose, where in people are effected the cases irreversible I say it could be Toxic Dose and I could have a TD 50.

In a while continue with this the response curve for Dose and response we find that the curve is sigmoid or non linear. And we will try to apply the form of this curve known as a Probate to quantify the damages and this is what we do in the next class well.

Thank you.