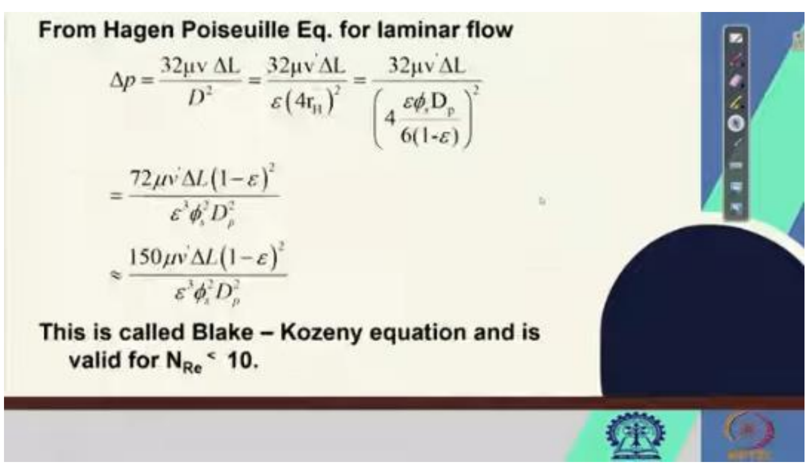
IMPACT OF FLOW OF FLUIDS IN FOOD PROCESSING AND PRESERVATION

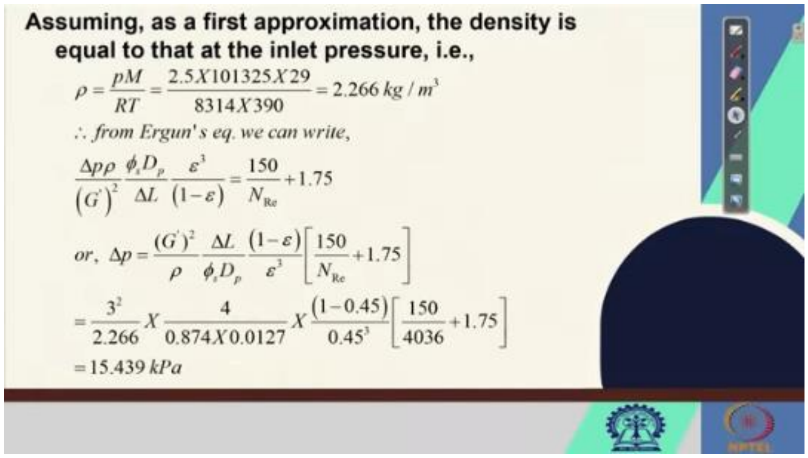
Lecture40

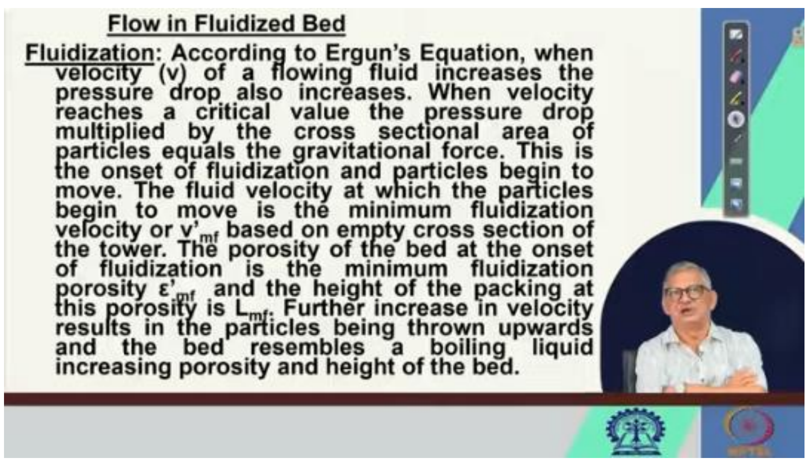
LECTURE 40 : FLUIDIZATION

Good afternoon, my dear students, boys and girls, and friends. So, you have completed, with the help of Ergun's equation, flow through a packed bed, right? There are many types of other packed beds, like fluidized beds, right? So, what do you mean by a fluidized condition? So, we come to that: what do we mean by fluidization?

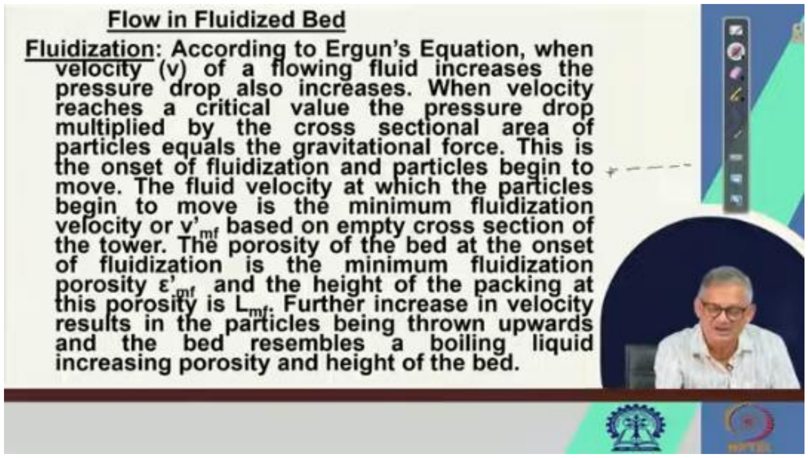


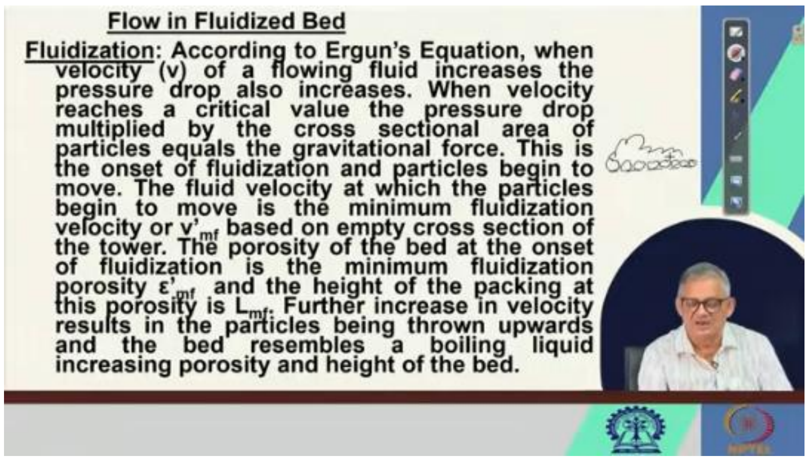
So, fluidization is like this: according to Ergun's equation, when the velocity v of a flowing fluid increases, the pressure drop also increases. According to Ergun's equation, when the velocity v of a flowing fluid increases, the pressure drop also increases. When the velocity reaches a critical value, the pressure drop multiplied by the sectional area of the particles equals the gravitational force. So, this is the onset of fluidization, right? So, let me draw. I hope, perhaps, after this, we will have some idea.

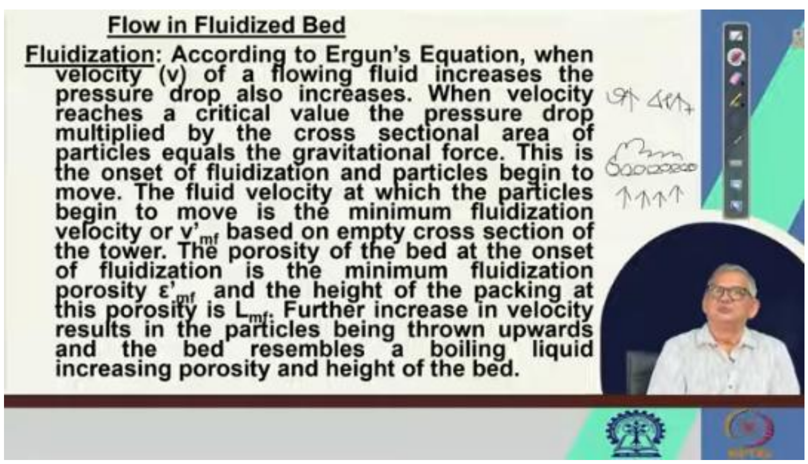




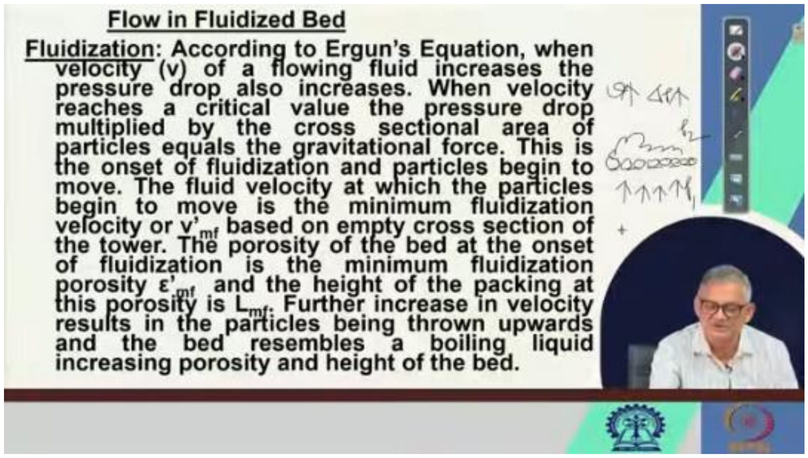
So, fluidization means you have a tray like this. And you have your materials to be conveyed like this or fluidized like this, and many, many others, okay? Now, you are blowing some air, which may be hot air or cold air, depending on what you want to do. So, what we have already said is that, according to Ergun's equation, as the velocity increases, delta P also increases, right? If the velocity increases, obviously, delta P will also be increasing.

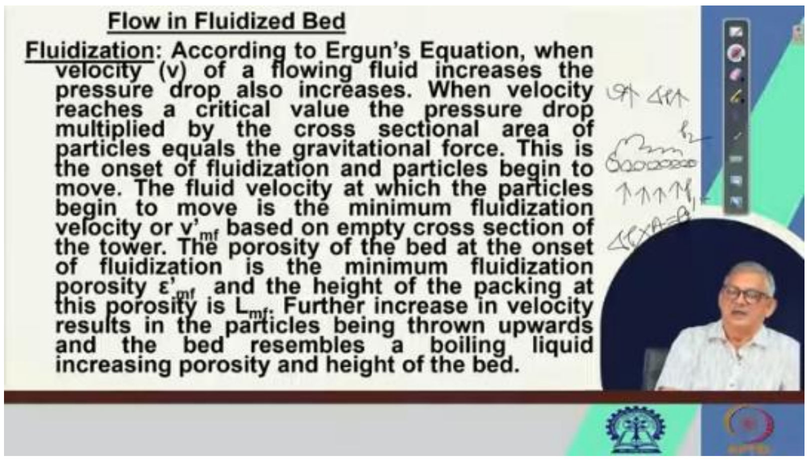






So, when the velocity reaches a critical value The pressure drop multiplied by the sectional area is equal to the gravitational force, right? So, this pressure drop is between P_1 and P_2, right? So, delta P multiplied by the sectional area A, right? This must be equal to the gravitational force, rho g, right? That means, this is the onset of fluidization, meaning a little more, and we will make it move or dance like that.





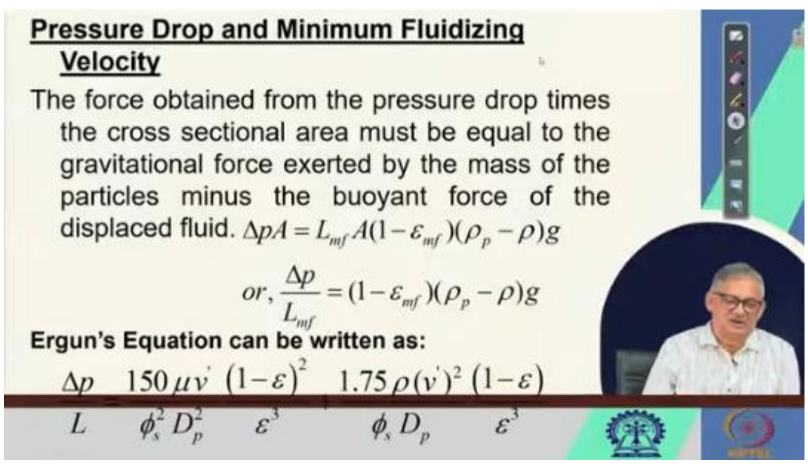
I hope you have seen, on many occasions, people use a ping pong ball, ping pong in the sense of a table tennis ball, like that, with a table tennis ball. The flow of water, or this can be said, the blow of water, right? At a height, you put this, and there, this phenomenon is applying, that is, your pressure drop times the sectional area equals the gravitational force, right? So, it starts dancing, right? Then

Then, this is called the minimum velocity of fluidization. The fluid velocity at which the particles begin to move, the fluid velocity at which the particles begin to move, is the minimum fluidization velocity. Or v_{mf}prime (v'mf), that is called based on the empty cross-sectional area of the tower. The porosity of the bed at the onset of fluidization is the minimum fluidization velocity or Sorry, the minimum fluidization porosity, that is epsilon$_{mf}$ prime (ε'mf), and is also based on the empty cross-sectional area, and the height of the packing at this porosity is also called L_{mf}.

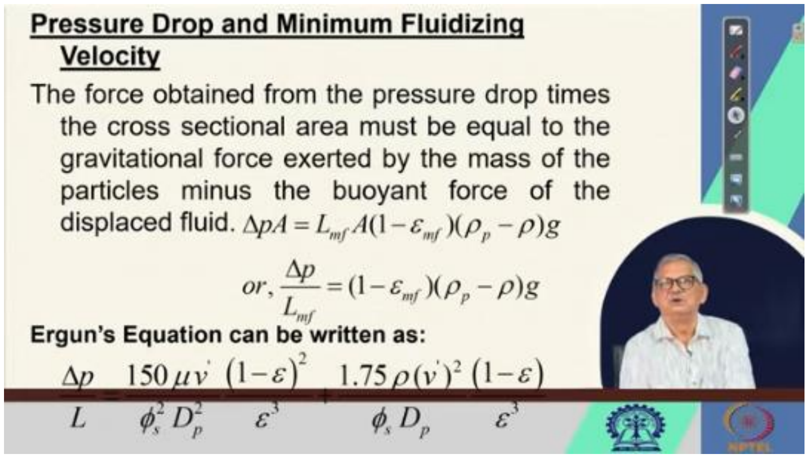
Further, an increase in velocity results in the particles being thrown upwards, and the bed resembles a boiling liquid. What happens when boiling occurs? So, bubbles do come, and it starts dancing like that. So, it appears that it is dancing, right, resembling a boiling liquid, right? And this increases the porosity and height of the bed when you are increasing the velocity, right.

So, for understanding, we repeat that according to Ergun's equation, When the velocity v of a flowing fluid increases, the pressure drop also increases. When the velocity reaches a critical value, the pressure drop multiplied by the cross-sectional area of particles equals the gravitational force. This is the onset of fluidization, and particles begin to move. The particle begins to move; the fluid velocity at which fluidization begins,

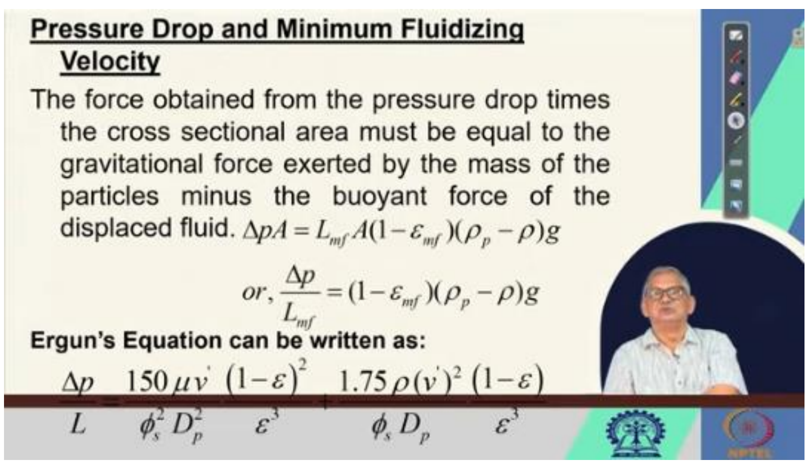
particles begin to move at the minimum fluidization velocity or vdot$_{mf}$ based on the empty cross-section of the tower. The porosity of the bed at the onset of fluidization is the minimum fluidization velocity, porosity that is epsilon$_{mf}$, again based on the empty cross-section. A further increase in velocity results in the particles being thrown upwards, and the bed resembles a boiling liquid, increasing the porosity and height of the bed. Now, pressure drop and minimum fluidizing velocity, what are those?

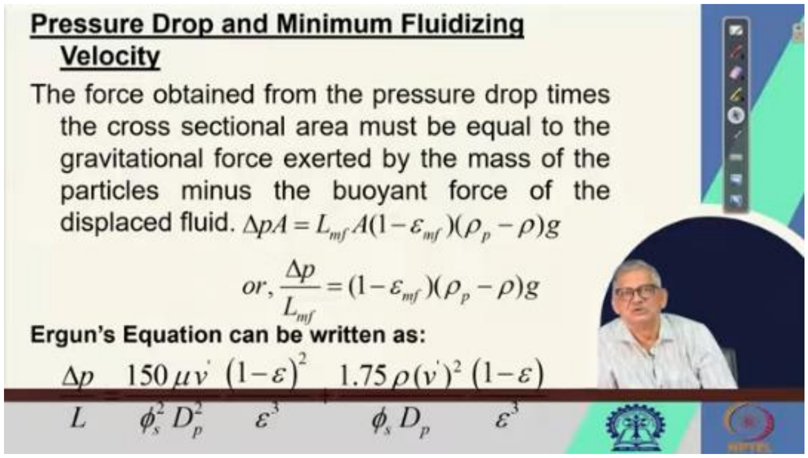


Pressure drop and minimum fluidizing velocity. The force obtained from the pressure drop times the sectional area must be equal to the gravitational force exerted by the mass of the particles minus the buoyant force of the displaced fluid. I repeat, the force obtained from the pressure drop times the sectional area must be equal to the gravitational force exerted by the mass of the particles minus the buoyant force of the displaced fluid, right.

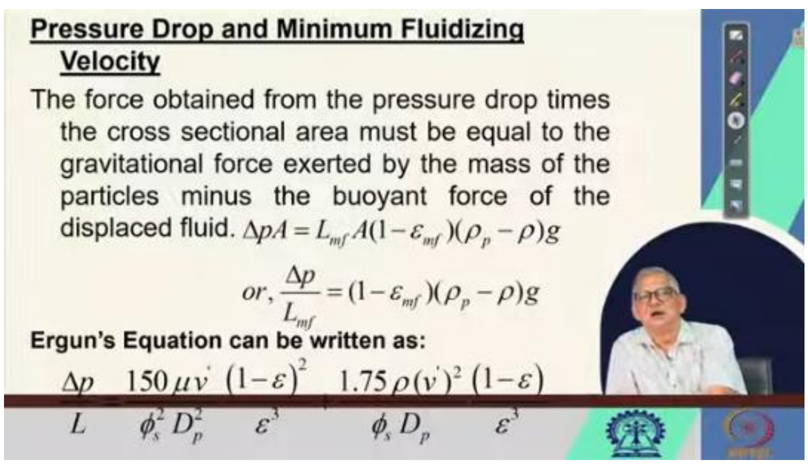


So, mathematically, we can write that delta P into A is L_{mf} into A into 1 minus epsilon_{mf} into rho_P minus rho into g, right. That rho_P minus rho into g is the buoyant force and the gravitational force, no, rho_P minus rho into g, yeah, that is the L_{mf}, and the pressure drop multiplied by the sectional area delta P A, must be equal to the gravitational force exerted by the mass of the particles minus the buoyant force of the displaced fluid, ok. So, it is one for the gravitational force and another for the buoyant force, that is, rho_P minus rho into g.

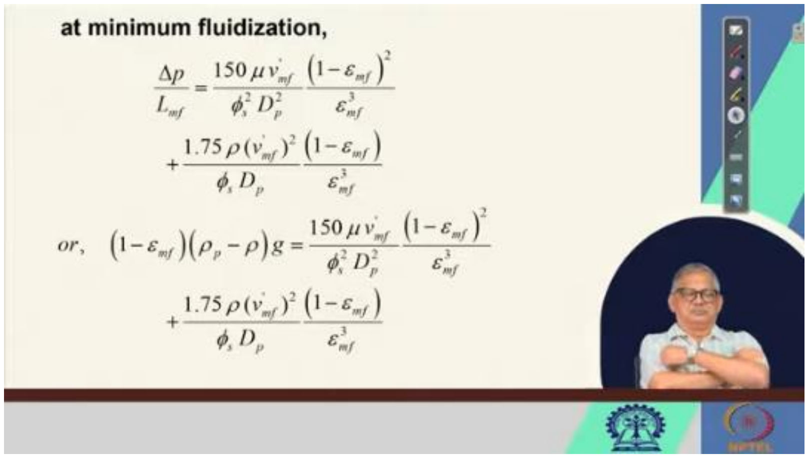




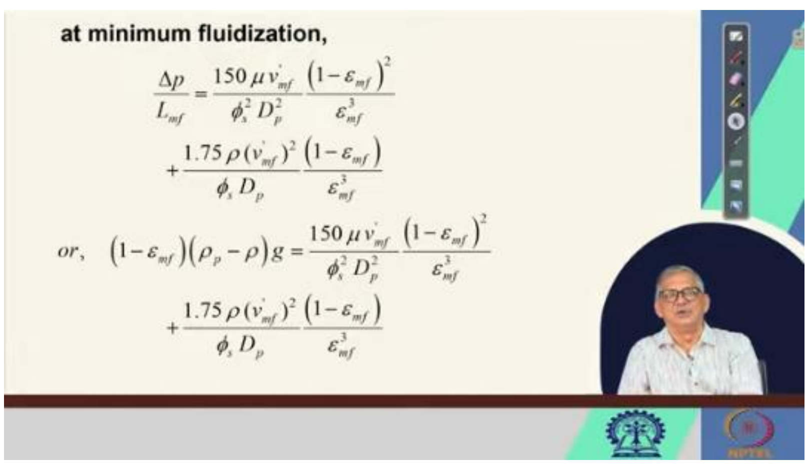
Right, L_{mf} A into 1 minus epsilon$_{mf}$ remaining identical, ok. Then we can write delta P over L_{mf} is equal to 1 minus epsilon$_{mf}$ into rho$_P$ minus rho into g, right. Now, if we put back the Ergun's equation as delta P by L into 150 mu v prime (v') into 1 minus phi$_s$ square D_p square epsilon cube is equal to 1.75 rho v prime square by phi$_s$ D_p into 1 minus epsilon by epsilon cube. So, this is what we got, the pressure drop



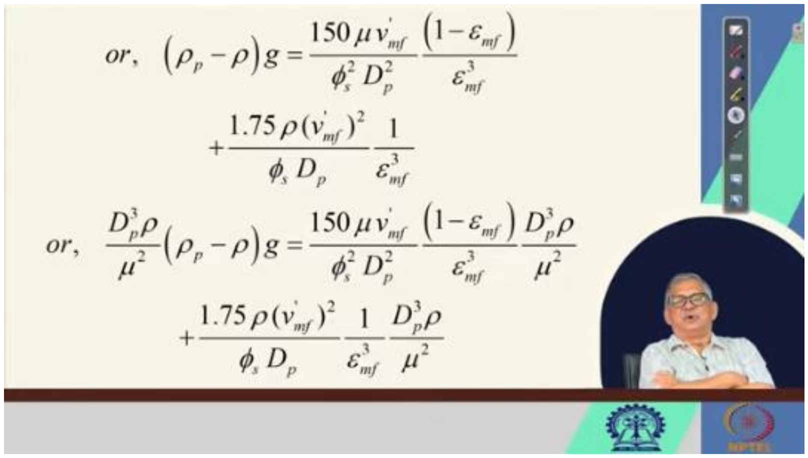
In minimum fluidization, we brought into the Ergun's equation. Now, the pressure drop at minimum fluidization velocity, we can write that this is the same; it has come, okay. It might have been copied, okay. Now, Ergun's equation we have shown just now. So, at minimum fluidization, delta P by L_{mf} is equal to 150 mu v_{mf}prime by phi$_s$ square D_p square



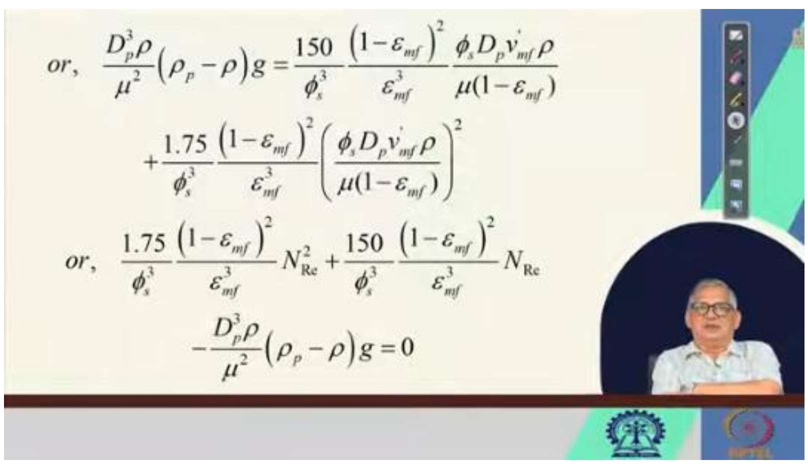
into 1 minus epsilon$_{mf}$ by epsilon$_{mf}$ square by epsilon$_{mf}$ cube plus 1.75 into rho into v$_{mf}$ prime whole square by phi$_s$ into D$_p$ into 1 minus epsilon$_{mf}$ by epsilon$_{mf}$ cube. So, we can rewrite that 1 minus epsilon$_{mf}$ into rho$_p$ minus rho into g is equal to 150 by phi$_s$ square mu v$_{mf}$ prime by D$_p$ square into 1 minus epsilon$_{mf}$ whole square by epsilon$_{mf}$ cube. plus 1.75 rho by phi$_s$ v$_{mf}$ prime square by D$_p$ into 1 minus epsilon$_{mf}$ by epsilon$_{mf}$ cube. So, we can rewrite that rho$_p$ minus rho into g. is equal to 150 mu into v$_{mf}$ prime, v$_{mf}$ prime over phi$_s$ square D$_p$ square into 1 minus epsilon$_{mf}$ by epsilon$_{mf}$ cube plus 1.75 into rho into v$_{mf}$ prime square by



phi$_s$ into D$_p$ into 1 minus epsilon$_{mf}$ cube. So, this we can write that D$_p$ cube rho by mu square into rho$_p$ minus rho into g is equal to 150 mu v$_{mf}$ prime by phi$_s$ square D$_p$ square into 1 minus epsilon$_{mf}$ by epsilon$_{mf}$ cube D$_p$ cube rho by mu square plus 1.75 rho by phi$_s$ into v$_{mf}$ prime square by D$_p$ into 1 by epsilon$_{mf}$ cube into D$_p$ cube rho by mu square, right? Or we can write that D$_p$ cube rho by mu square into rho$_p$ minus rho into g is equal to 150 by phi$_s$ cube into 1 minus epsilon$_{mf}$ whole square by epsilon$_{mf}$ cube into phi$_s$ D$_p$ by vmf prime into rho by mu into 1 minus epsilon$_{mf}$.



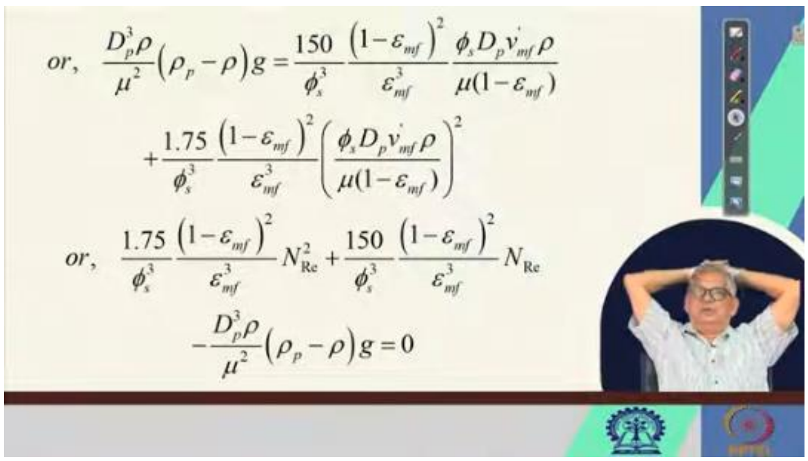
Plus 1.75 by phi$_s$ cube into 1 minus epsilon$_{mf}$ whole square by epsilon$_{mf}$ cube into phi$_s$ by mu into D_p into v_{mf} prime rho by mu into 1 minus epsilon$_{mf}$ whole square. This we can rewrite as, 1.75 by phi$_s$ cube into 1 minus epsilon$_{mf}$ whole square by epsilon$_{mf}$ cube into N_{Re} square plus 150 by phi$_s$ cube into 1 minus epsilon$_{mf}$ square by epsilon$_{mf}$ cube. N_{Re} minus D_p rho by mu square into rho$_p$ minus rho into g equal to 0. So, here you see that somehow from Ergun's equation it has been modified to a quadratic equation of



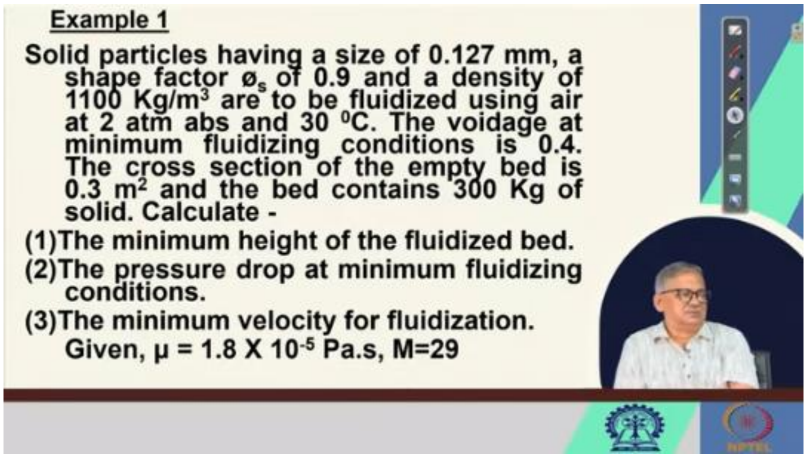
N_{Re}, right. With respect to Reynolds number, a quadratic equation has been established where obviously there is some coefficient like. 1.75 by phi$_s$ square or phi$_s$ cube into 1 minus epsilon$_{mf}$ whole square by epsilon$_{mf}$ cube. This we can say as A N_{Re} square plus 150 by phi$_s$ cube into 1 minus epsilon$_{mf}$ whole square by epsilon$_{mf}$ cube. This we can say to be B N_{Re}.

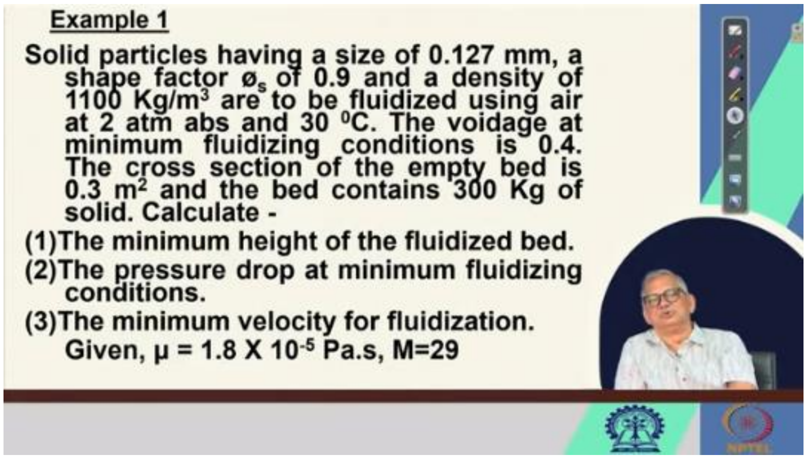
So, A N_{Re} square plus B N_{Re} minus D_p rho by mu square into rho$_p$ minus rho into g equals to 0. A N_{Re} square plus B N_{Re} minus C is equal to 0. This is a quadratic equation or quadratic term, right. The thing is that if we can solve this quadratic equation in terms of N_{Re}, we get the value. Then from the definition of N_{Re}, which we have already used, right, we can find out what is.

Velocity because from N_{Re}, we know that N_{Re} is equal to D v rho by mu. So, either diameter or velocity we can find out or D v rho. So, rho mu any other things are given. So, one unknown can be found out. This is a unique development from the Ergun's equation, right. So, if we look at a problem solution, then it is said that, solid particles having a size of 0.127 millimeter or shape factor of phi_s of 0.9 and a density of 1100 kg per meter cube are to be fluidized using air at 2 atmosphere absolute and 30 degree centigrade. The voidage at minimum fluidizing conditions is 0.4. The cross-section of the empty bed is 0.3 meter square and the bed contains 300 kg of solid.

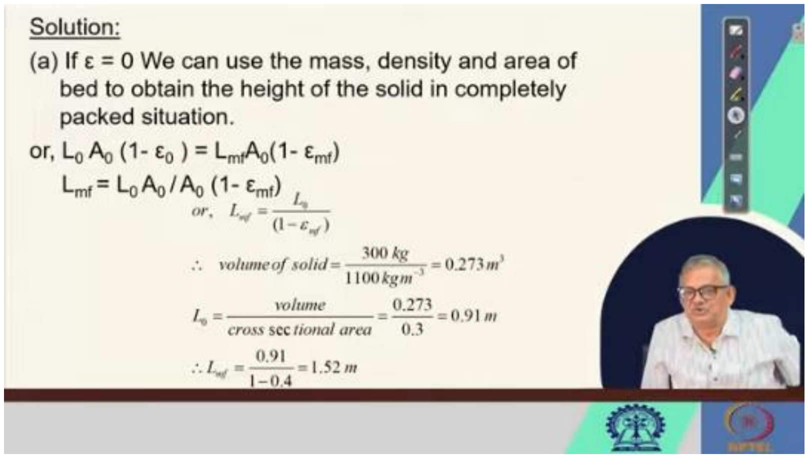


Then calculate the minimum height of the fluidized bed, the pressure drop at minimum fluidizing conditions, and the minimum velocity for fluidization. Of course, given things are mu is 1.8 into 10 to the power minus 5 Pascal second, M, 29, right. So, you see minimum fluidization or velocity of fluidization these things can be determined very easily. So, we read the problem: solid particles having a size of 0.127 millimeter, shape factor of phi s of 0.9, and a density of 1100 kg per meter cube are to be fluidized using air at 2 atmosphere absolute and 30 degree centigrade. The voidage at minimum fluidizing conditions is 0.4, the sectional area of the empty bed is 0.3 meter square, and the bed contains 300 kg of solid.

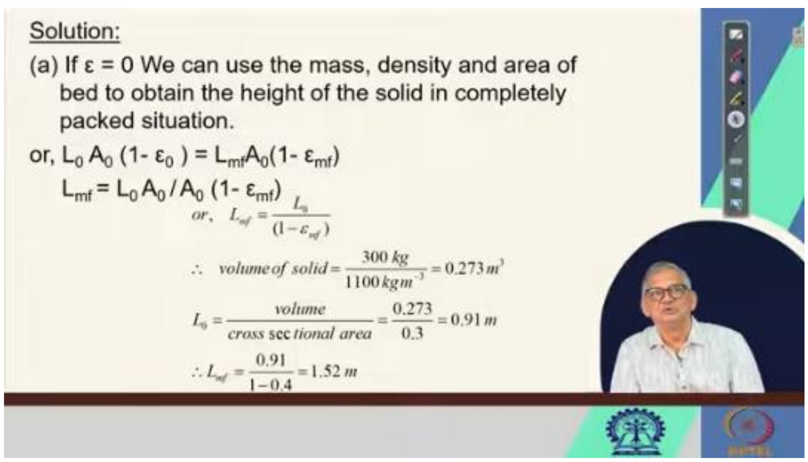




Calculate the minimum height of the fluidized bed. The pressure drop of minimum fluidizing conditions, and number 3, the minimum velocity for fluidization, given, mu is 1.8 into 10 to the power minus 5 Pascal second, and molecular weight is Mair equals to 29, right. So, if you want to solve it, Then let us take this situation: had there been no porosity, that means, if epsilon would have been 0, then we can use the mass density and area of the bed to obtain the height of the solid in a completely packed solution, absolutely true. We write L_0 A_0 is equal to; L_0 A_0 into 1 minus epsilon_0 is equal to L_{mf} into A_0 into 1 minus epsilon_{mf}.



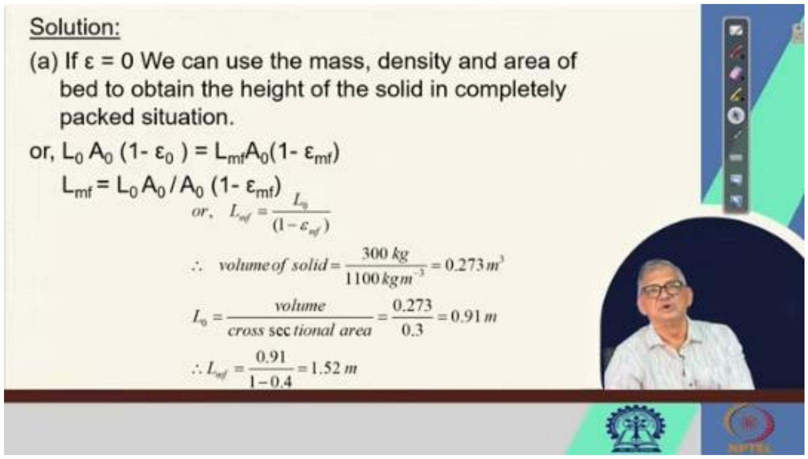
So, L_0 A_0 into 1 minus $epsilon_0$ equal to L_{mf} into A_0 into 1 minus $epsilon_{mf}$. So, L_{mf} is L_0 A_0 by A_0 into 1 minus $epsilon_{mf}$. L_0 A_0 by A_0; L_0 A_0 by A_0 is L_{mf}. So, there we have missed one, the 1 minus $epsilon_0$ and 1 minus $epsilon_{mf}$, right. So, from there we can write L_{mf} is L_0 by 1 minus $epsilon_{mf}$, right. $Epsilon_0$ is equal to 0, so that means, L_0 A_0 into 1, right.



So, L_{mf} is L_0 A_0 by A_0 into 1 minus $epsilon_{mf}$, or L_{mf} is equal to L_0 by 1 minus $epsilon_{mf}$. Therefore, the volume of solid is 300 kg per 1100 kg per meter cube density. Therefore, the volume of solid is 0.273 meter cube. L_0 is volume by cross-sectional area is 0.273 by 0.3 is equal to 0.91 meter. Therefore, L_{mf} is 0.291 divided by 1 minus 0.04 that is 1.52 meters. So, the minimum height of fluidization, we have found out based on epsilon equals 0, right. So, we have decreased the Mass we have decreased, we can use the mass density and area of the bed to obtain the height of the solid in a completely packed situation. Right.

So, if we know L_0, A_0, 1 minus $epsilon_0$, $epsilon_0$ is 0. So, it is L_0 A_0 equals M f l a l a 0 into 1 minus epsilon. So, that L_{mf} is L_0 A_0 by A_0 into 1 minus $epsilon_{mf}$ Therefore, L_{mf} is L_0, A_0, A_0 goes out, into 1 minus $epsilon_{mf}$. Volume is 0.273 because 300 kg per 11800 kg per meter cube is 0.273 meter cube. Where L_0 is volume by sectional area is 0.273 by 0.3 that is 0.91 meters.

So, L_{mf} is 0.91 divided by 1.04 that is 1.52 meters. I know that the problem is not over, we will carry forward in the next class because time is up, OK.



Thank you.