Iron Making
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Lecture – 13
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Now, we will come to one numerical problem, of them.

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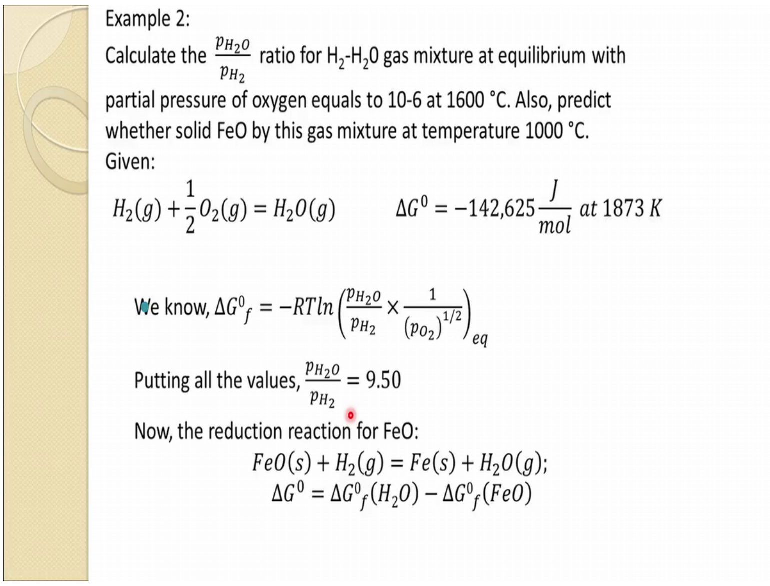

So, the first is, calculate a p H 2, H 2 O and H 2 ratio for hydrogen and water gas mixture at equilibrium, with partial pressure of oxygen 10 to the power minus 6, at 1600 degree Celsius. So, this is given, the reaction; hydrogen reacting with the oxygen, which giving you water all are gasses, and the free energy data is given, for that at 1600 degree Celsius or 1873 Kelvin. As you know the, from the free energy the equilibrium constant of this would be p H 2 O divided by p H 2 and into p O 2 to the power half that is ok.

So, we substitute the that one the free energy expression. So, R T log k. So, the substitute that equilibrium and we, from this one because delta g is given, and put it here R and T are known, we can and this also, oxygen partial pressure is given 10 to the power minus 6. If we substitute all these value, we can calculate the ratio of p H 2 O to p H 2 which is about 9.5. So, so that is our first question to calculate the ratio of partial pressure of H 2 O to hydrogen. Now it has also predict whether solid F e O by this gas mixture at temperature 1000 degree Celsius. So, it actually; it says a whether solid F e O can be reduced um. So, something is missing, it is a whether solid F e O can be reduced by this gas mixture at temperature 1000 degree Celsius.

So, now if we take the reduction of that, with hydrogen. So, this is the equation, and then we can get from subtracting this free energy data.

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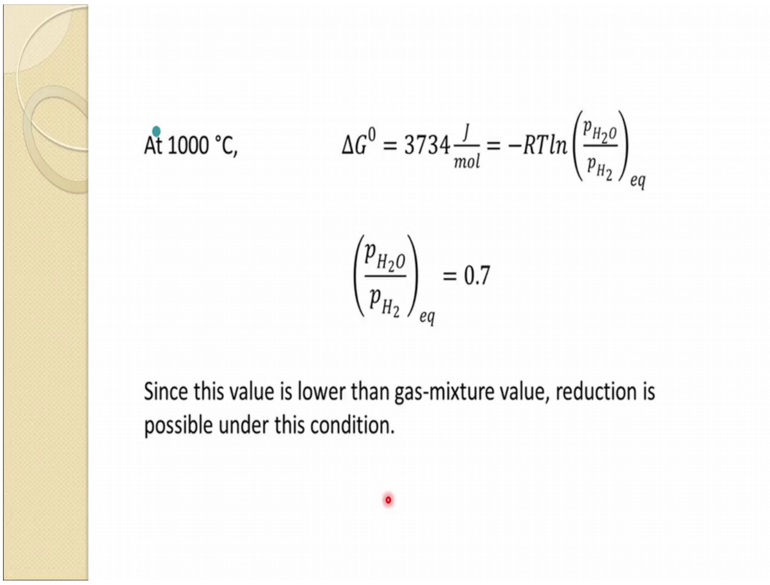

So, that give the free energy of 3 7 3 4 joules per mole, and the equilibrium constant is p H 2 O over p H 2. So, if we substitute all the values temperature here would be 1273 degree kelvin, and this is a universal case constant. So, you get p H 2 O p H 2 ratio 0.7. So, in that way really your partial pressure, so hydrogen has increased, and which is a more reducing one. So, if you look at that where they said increase, this ratio to redu to reduce F e O, this ratio are reverse of that should be higher or this should be lower.

So, under this condition actually actual one is 9.5. So, its bit lower. So, 0.7 which means this put this mixture can reduce the F e O under this condition. Ok. Because this free low value, more hydrogen is there; and at 1000 if you recall our F e O H system, which we talked before; and there we said after 821 degree Celsius, hydrogen reduce reduction potential is much more than the C O. And certainly this mixture would be able to reduce boostite into iron.

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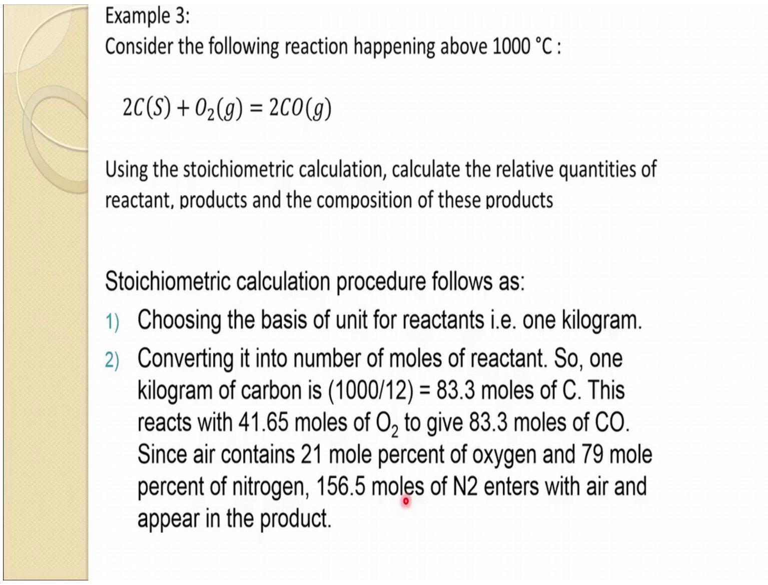

Is another example um. So, consider the following reaction, carbon broadening its sort of occurring at 1000 Celsius. So, use using the stoichiometric calculation, calculate the relative quantities of the react reactants products and the composition of these products. So, if we choose we can always choose some sort of unit basis like we had chosen chosen before one more, now be choose one kilogram. So, converting it into the number of moles for reactant. So, one kilogram of carbon would be 88, 83.3 moles. So, that normal ways you know about to convert it into the moles. Similarly you can convert the oxygen and C O also, in in terms of moles.

Now, air contains about 21 mole percents of oxygen and 79 mole percents of nitrogen. So, which, which again to convert, it this will give you, in terms of moles because this is percentage, 156.5 moles of nitrogen enters with air and appears in the product. So, whatever nitrogen is appearing here, and the air will just come out as a product; as we know nitrogen and does not react to these any other product with our reactant which are present air at that temperature especially.

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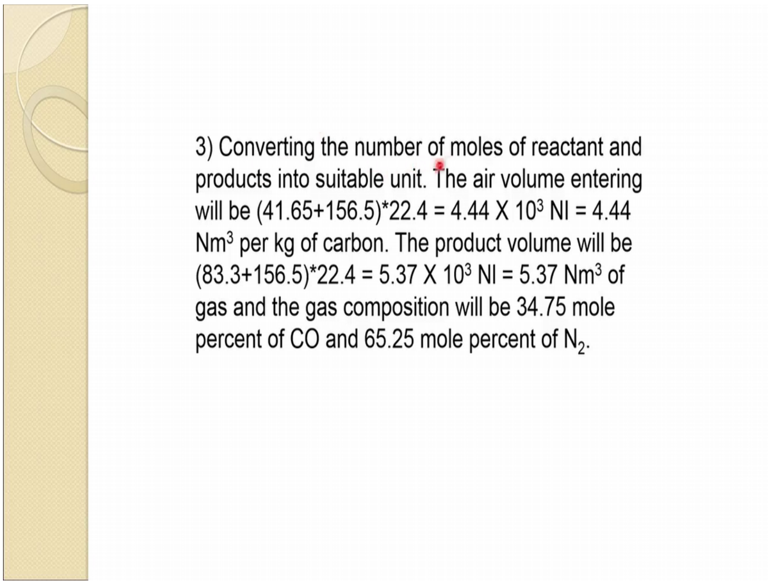

So, knowing that converting the number of moles of reactant and products into suitable unit, and air volume also entering; you know this is oxygen and nitrogen, we calculated here oxygen moles and nitrogen moles. So, and we multiplied with a 22.4 at you know, at s t p the volume of the gas. Then you can get 4.4 into 10 to the power 3 normal leta.

So, this unit is normal leta, which you convert into normal meter cube per kg, but we these of carbon. Similarly the product for um, C C O is coming out; if you look at this one is C O is coming out, and nitrogen. And C O, we calculated 88.3 moles so that is one and the nitrogen can multiply with the volume, you get normal meter cube of gas. So, gas composition would be, now you can convert that one again h v, when you know reverse form what we did here. So, you will get 34.7 mole percent of C O, and 65.25 mole percent of nitrogen, in that way.

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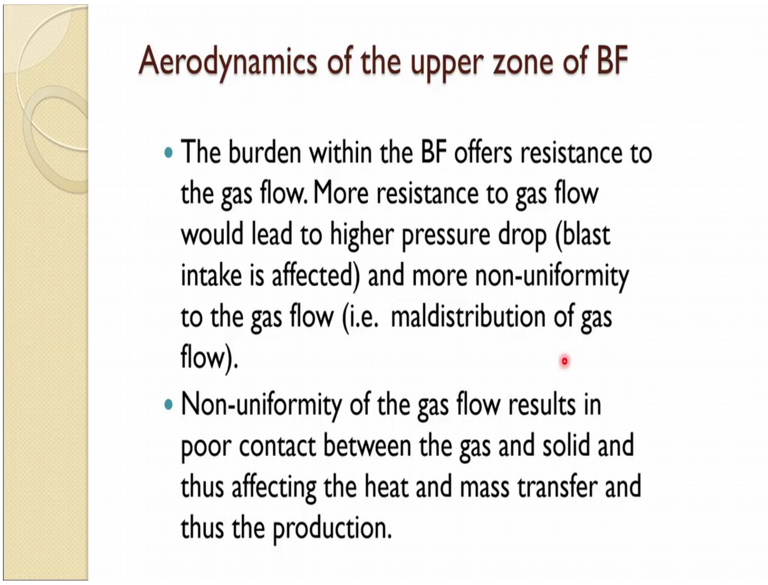

So, now, actually we are going to go to another topic. Till now we talked about the physico chemical phenomena, which is occurring in the blast furnace, in short. And some sort of mass balance also we dealt with, not much with the heat balance, but after knowing this physico physicochemical chemical phenomena and the um, charge which we talked about carbon, hematite limestone, and their size, their preparation; all these things. And many times we talked about the pressure drop of permeability of the burden of the charge without knowing what is it.

So, we come to another topic like the aerodynamics of the upper zone of blast furnace. So, in this lecture, I will be talking more about the upper zone of the blast furnace. um. When we say aerodynamic, mostly you are talking about the air flow or gas flow, in the blast furnace. So, the burden with in the blast furnace offers resistance to the gas flow. um. Assume if there is ago um, jet retriever, or blast furnace is there without any material. So, gas will not have any sort of resistance for the flow. So, it will just go without much resistance to the top. But if you put some materials, so, naturally that material will offer the resistance to the gas flow, and gas will always like to pass through the least resistance path.

So, when you are putting the granular material especially. So, that it will form some void. So, gas will try to pass through the least resistance path, that is through those voids. So, more resistant to gas flow up would lead to high pressure drop. So, that void, if they are smaller and smaller, it is or in one way the resistance is more, it will lead to higher pressure drop and blasting intake is affected; that which you are putting from the bottom. And your pump capacity everything is going to get affected, and that is the more non uniformity of the gas flow, or in one way the maldistribution of gas flow what we call it will occur, in the region. So, non-uniformity of the gas flow results in poor contact between the gas and solid and thus affecting the heat and mass transfer, and thus the production because gas always will try to take a least resistance path.

So, what it will do, it may bypass some of the force or voids, and where the; it is a least resistive near the wall, and like that it may go through that. So, in terms what is going to happen? There would be a very less gas and solid contact, and gas is the C O and when nitrogen, which is coming which a gives the sensible heat to this charge and C O also takes part in that reduction. So, that is not going to take place effectively. So, that is going to affect the heat and mass transfer. So, gas flow phenomena is most important in the blast furnace from products and viewpoint, and that is why this topic is about aerodynamics; we called it.

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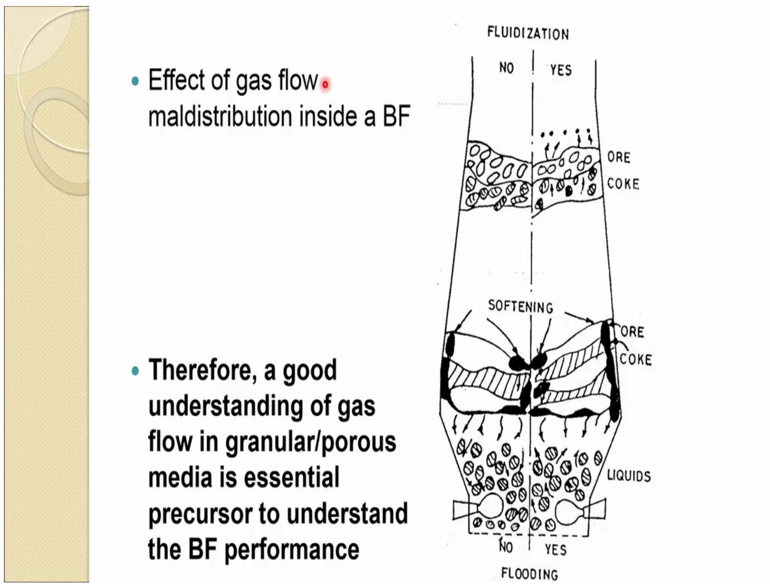

So, to understand that brief. So, effect of gas flow in the blast furnace, probably this will gives you a little better idea, this picture. So, though case is coming in through the tia and burning it over here in front of the tia, producing reducing gas C O and nitrogen. And, in this reason boasts reason or dropping zone; bailey in boast reason what we call is as a dropping zone, in this one only coke particles they are in solid; and select and liquid iron is coming down. So, and when you are having high gas generation C O and nitrogen here, this liquid offered the resistance to the gas flow.

So, now gas is not check getting the resistant through this solid present here or even from the liquid. So, very complex situation of over here and this may lead some time to flooding and stopping of the blast furnace event. So, there that is a very bad condition for the products on and as you go up. So, if you do not have a good permeability, this is showing the coke layer which is porous in nature because coke is a like here it retains its shape. So, it is particles and between the particle bolts are there. So, gas can pass through it; however, ore kept semi filled. So, the force between the particle ores get reduced. So, very less permeability; that is what we are calling about permeability, means with quite a low void fraction in the gas and ore region where semi future. This region it is more about the cohesive zone, where semi field material it they are.

So, gas is mostly passing through the coke. So, if coke layer is not there separately, it is very difficult for gases to pass from here. And because they can they have a very high resistance here. Then you have a problem here. Then once it goes; so, this is the normal operation if you have a good permeability, good these boidice in the coke layer. It can then pass gas through here. Now, if you come to the upper region, again the same problem coming, it is about the burden distribution. Now, if you do not have a uniform particle size, and the narrow range of distribution of the particle; you are going to have a problem. Because if it is not a narrow range size, the smaller particles can fill up these boiled increases, and then will offer more resistance to the gas.

So, again there is a problem about the pressure drop per increment. And now very fine particle; because gases, gas has to pass through this in, so, through increases. So, essentially the velocity of the gas increases quite a lot through these bolts. So, in and sometime, this velocity can be that high and the; when a small particles are there that can be carried away, what you call the fluidization. In fact, of those particles are we called elutriation; and this particle can carried out and outgoing gas. So, you are losing quite a bit and fludization sort of thing is occurring all over here. So, that is why death crepitation and all those properties which we talked about, the material becomes very very important, due to this gas learn things.

So, all these things what we have talked in now are related to this aerodynamics of the blast furnace, and due to which we need all this elaboration about the preparation of raw material and everything; because that should satisfies all these condition here otherwise your gas flow will be erratic, and all your products and even the blast furnace performance would be erratic. So, this is very important part. So, we will start with a little basic of it, as many of you may not be aware about the some of the term. So, therefore, a good understanding of gas flow in granular or porous media is essential the precursor to understand the blast furnace performance.

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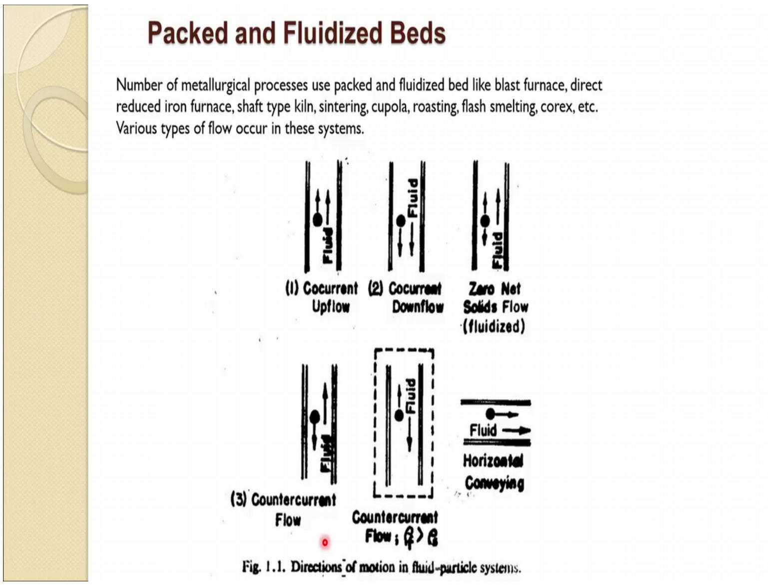

So, we will go little bit to a basic of the thing. So, so packed bed and fluidized bed. So, when this granular material is packed like this, we call later the packed bed; and when it is particles are flowing away, and they are not in contact, usually call it the fluidization of that. Jet every in a rough way I am telling you about the meaning of this. So, in metallurgical processes, we have many of those packed bed and fluids bed reactor, blast furnace, direct reduced iron furnace; so type in sintering, which we had discussed; cupola, roasting, flash smelting, corex, etcetera. And in all of these pet, not just one type, various type of flow occur in these system. Co current up flow, where the solid and fluids are flowing in the same direction are travelling. And then co current down flow; where solid and fluid; fluid we are using because, fluid can have anything; either gas or liquid.

So, the common word is fluid for that, when you refer it. So, it could be gas or liquid. So, down co current down flow, the solid and the fluid are travelling down together. And you remember this is the one situation which we discussed just now for the blast furnace co current indirect reduction process, in which we showed that, that is quite inefficient, and the consumption of the coke is the maximum about 1060 kg coke is needed per ton of iron.

So, that it is one of the example which we took also this is about the fluidization or 0 net solid flow. So, where your solid particle is just suspending in the fluid, and fluid is having that much velocity which is just able to suspend it is or um fancy gravity, and the drag force are getting balanced here and it is just in a suspended form; but fluid is moving, but not the particle solid. Then you have a counter current flow where solid also has the sufficient, now under gravity and other forces not balanced. So, solid is also moving down, and fluid is moving upward direction; and this is the situation occurs in blast furnace.

So, that is why we called the blast furnace as a counter current reactor. So, that is a counter current flow; solid is moving down and fluid is moving up. And then, you have n another one where, solid is moving up and fluid is moving down. That is happened when the fluid solid has a lower density than the fluid; in that concision solid is moving up in fluid is going down. And you can have a horizontal, this conveyor where it is solid and fluid moving in the same direction. Besides that, we there only few, but there are some other, one is cross flow. If you look at you know about the sintering, we talked about the sintering. So, in sintering the suction is occurring from the bottom.

So, gas it traveling like this; and sintra a strand is moving in this direction. So, it is like a cross flow. So, gas is moving perpendicular to the solid movement. So, that type of flows you call the cross flow. So, like this as you can help you other flows. So, that gives you the idea of different types of these three flows; you are already aware of it.

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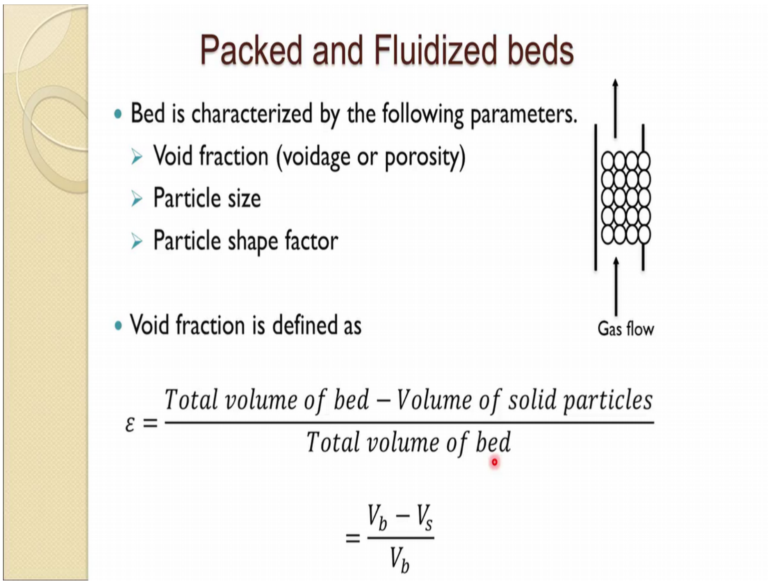

So now, how do we define the packed bed? Ok. So, packed bed has a character is characterized by the following parameter. One is the void fraction voidage or porosity what we call it between the particle, particle size, particle shape factor. So, if you take this one figure till it said shifted a little decide. So, there is a container or the tube. So, can assume and packed with the particles in which uniform size particles. So, you can see the bolts are formed between the particles. So, there is nothing except the gas.

So, when you are injecting the gas through this. So, gas has to pass through these bodice. So, that is the one through, one of the characteristics of the bed, the bodice of porosity what we call it this one, void fraction, particle size and particle separator. At in this one, we have assumed that one particle, and that to also a spherical; you can have a even cylindrical particle, a uniform one; and you can have in the mixed particle any shape. So, the void fraction, how it is defined is the total volume of the bed, minus volume of solid particle, divided by the total volume of the bed. So, if the total volume of the bed is V b minus V s divided by this.

So, in a non dimensional vector unit less quantity, like sorry. So, this gives you the void fraction of the bed. So, whenever you talk about the packed bed, question would be asked; what is the void fraction?. So, the void fraction meaning is this. Then the diameters of, of a sphere or the, of equal volume to particle score the volume equivalent diameter. So, usually you define the packing of these in terms of volume equivalent diameter of the particle.

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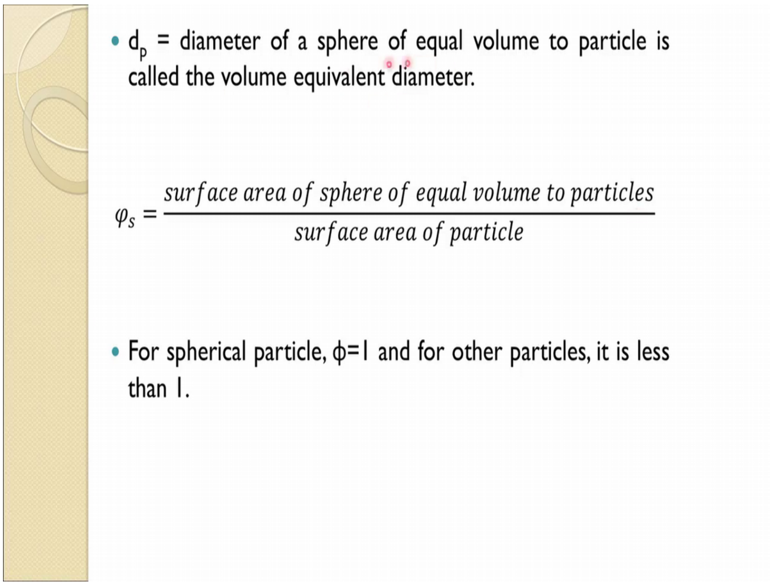

Um and then, you have a like a shape factor, such a surface area of a sphere of equal volume of 2 particle, and surface area of the particle, that gives you the shape factor.

So, if you take a spherical particle; it is a surface area of this sphere of equal volume 2 particle, it is a surface area of sphere, and um, and then surface area of the particle and your particle is spherical. So, that is really cancelled out; it will give you 1. So, a spherical particle the shape factor is 1, but for other type of particle, if they are not a spherical; you can calculate the shape factor and which should be multiplied with the equivalent diameter and that will give you the effective particle diameter.

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Material	Shape Factor, φ_s
Ottawa sand(nearly spherical)	0.95
Sand(angular)	0.73
Tungsten powder	0.89
Flue dust(aggregates)	0.55
Flue dust(spherical)	0.89
Crushed coal(up to 3/8 in.)	0.65
Pulverized coal	0.73
Silica powder	0.55-0.63
Berl saddles(packing material)	0.30

And they are different shape factor for various, a quite well known material. So, for pulverized coal like, shape factor is 0.73; when you say about 100 microns size of pulverized coal, really you have to multiply with 0.73 to get the correct equivalent diameter of that. Similarly, like silica powder flue dust. So, and this can be even measured it is not there, but these are the few well known material.