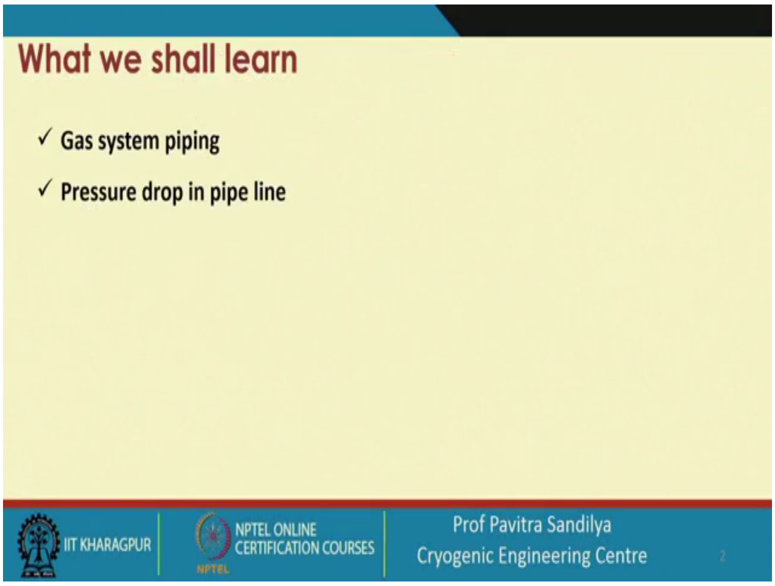
Upstream LNG Technology
Prof. Pavitra Sandilya
Department of Cryogenic Engineering Centre
Indian Institute of Technology, Kharagpur

Lecture – 84
Piping in natural gas systems – II

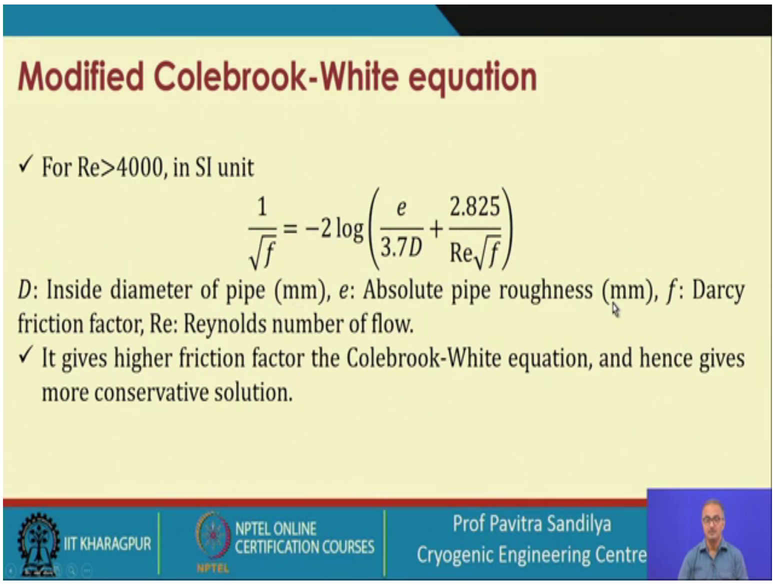
Welcome, after learning, about the fundamentals of the friction factor calculate determination and there are pressure, determination in the pipelines. We shall now be looking into, the more about the friction factors which are there in the expressions for the, flow rate, and these friction factor expressions have been suggested by various researchers for various types of, flow regimes for various types of systems.

(Refer Slide Time: 00:45)



So, we shall be looking into those which are used for the, natural gas systems.

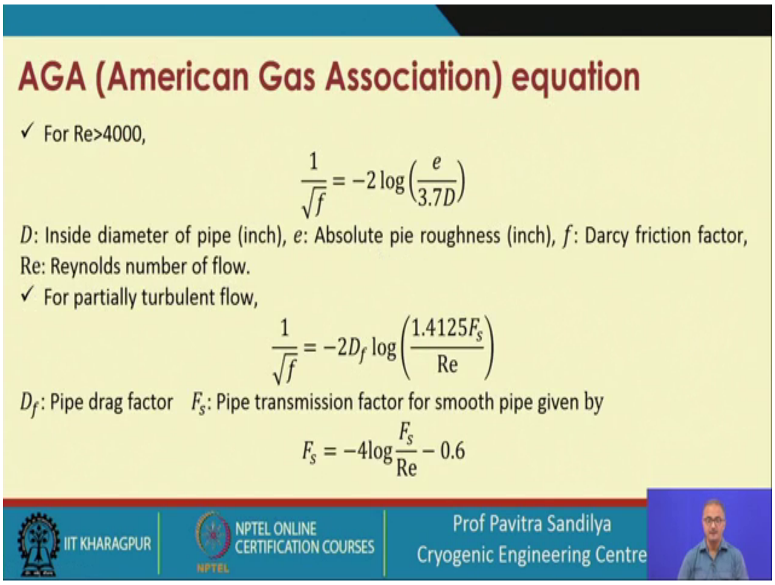
(Refer Slide Time: 00:47)



And in this first, we shall see the Colebrook-White expression and in this we find that in the FPS system for a large number more than 4000 is given by this particular expression. So, in this we find that the diameter and the, roughness factor is given in terms of inches and. So, and this particular expression is we find that this first term is signifying the roughness effect and the second term is signifying the Reynolds number effect.

And this expression is implicit in friction factor. So, that we need to use some kind of numerical technique to find out the value of the friction factor for example, you may use the Newton Raphson method, and similarly the same equation can be given in terms of SI unit and in this case we have to use the appropriate units for the roughness factor and the diameter of the pipeline and this is the expression we get for the, friction factor again in then implicit manner.

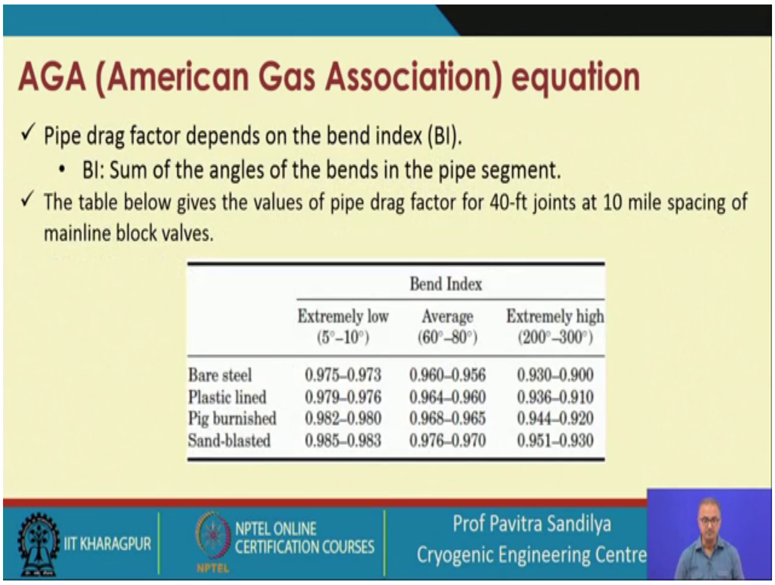
(Refer Slide Time: 01:47)



Now, for the American Gas, Association that is AGA, there is another equation, for the, this Reynolds number and this is given in terms of the, this, friction factor and this, we know that this is, for a rough pipe, and here we have For partially turbulent flow we have this particular expression, and, mind it that all these things are in the FPS units ok, then that is how this particular, quotient is 1.412 or 3.7.They are coming due to the particular, this, this expression of this unit system.

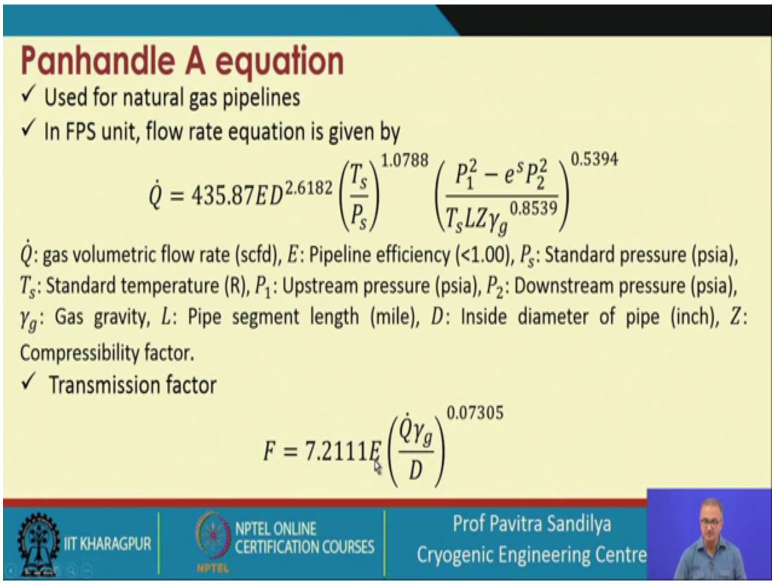
And in this case the pipe transmission factor for a smooth pipe is given by this particular thing this fs is coming over here. So, the fs is given in terms of Reynolds number and again we find this fs is coming as a implicit way. So, again we need to solve using some kind of numerical technique to find out the value of the fs.

(Refer Slide Time: 02:49)



And here with a drag factor which is, coming in this expression of the friction factor this drag factor, is generally given on the, depends on the bend index. So, there are depending on the number of bends in the pipeline and this bends cause the form drag. So, this change in the direction called the form drag. So, this form drag will depend on the number of bends, we have in the pipeline and, in this particular table we find the bend index have been given for various types of angles of the direction that 5 to 10 degree the 60 to 80 degree 200 to 300 degree. So, these are various types of, bends available and these are the various types of pipeline and depending on the type of the material of the construction we find that we have different types of bend index. So, this drag factor will depend on the bend index.

(Refer Slide Time: 03:41)



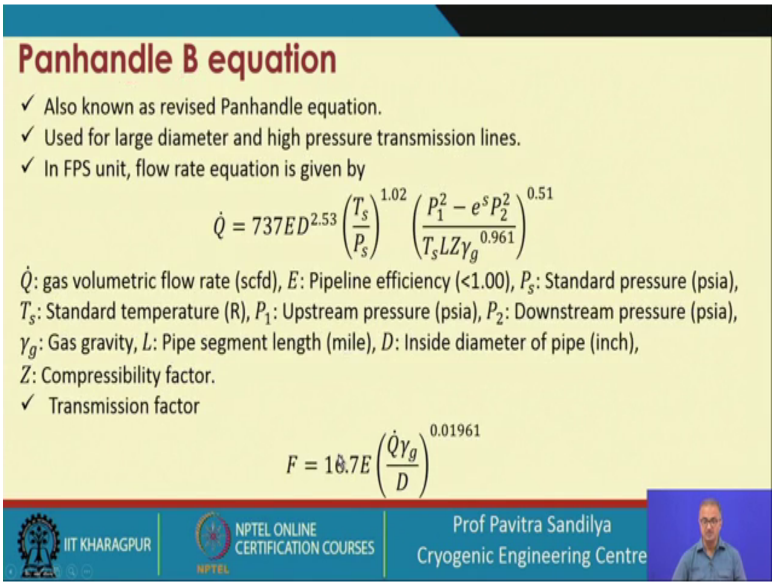
And now, we have another, equation that we call the Panhandle equation, and this equation is for natural gas pipelines and FPS system this is the particular expression of the Panhandle a. Now, please understand you do not have to need to remember these expressions that you should be aware of the various types of expressions available in, literature and whenever needed you can just refer to these expressions directly from literature and find out.

So, there is no need to really, memorize these expressions. So, you will find in this expression that depending on this FPS system you have unit; this particular constant has been given this value and here we find that we have a Pipeline efficiency which is less than 1 and then the other Standard temperature pressure the inlet and outlet pressures and this e s is as we found out taking care of the elevation effect and again we have all the Compressible defector, length of the Pipeline and the Gas gravity.

Now, we can give the same thing that the frictions, this, Transmission factor can be given in terms of this thing, that it is again depending on the, the efficiency, Pipeline efficiency and this is the volumetric flow rate that Inside diameter and the Gas gravity this is a Transmission factor.

And now, the same thing panhandle a equation is given in terms of the SI units and again you find that this particular value has changed and rest of the things remain the same and again we find that the Transmission factor value, is given by this and again this expression has changed a bit due to the change in the, particular constant.

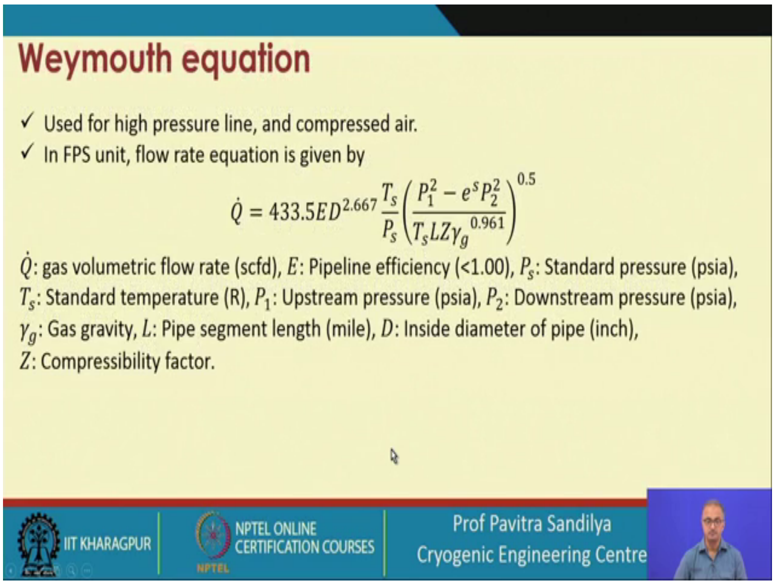
(Refer Slide Time: 05:20)



Now, we have another equation that is the Panhandle B equation and this Panhandles B equation is kind of a revised form of the Panhandle A equation and this is generally used for large diameter, and high pressure transmission lines. So, in this case in the FPS system the Panhandle B equation is given by this factor you can see, that the basic structure of the equations remain the same only difference has come in the values of the various types of the coefficients used in these particular expressions.

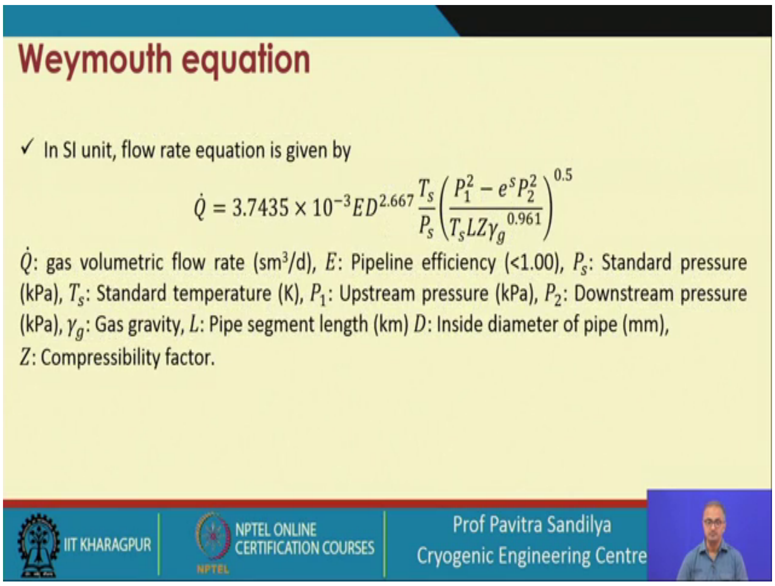
So, only the values have changed because of some change in the, some more physics have been taken into account in this Panhandle B equation we are not going to detail of this. And this is the, expression for the Transmission factor and similarly, we have the Panhandle A equation for the SI units and this is the expression for this particular equation.

(Refer Slide Time: 06:24)



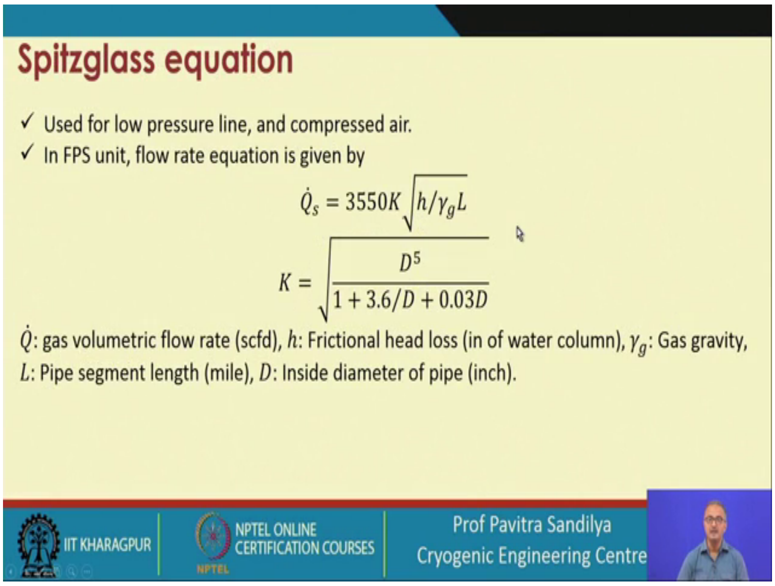
Now, another popular method is Weymouth equation and this Weymouth equation is used for high pressure pipelines and for example, also we may use used for compressed air. So, in this case for FPS system of units we find this is the expression for the volumetric flow rate by the Panhandle, expression and here again we find the similar the equation looks, similar to the Panhandle A or Panhandles B, only thing is this here the values of the coefficients have been changed.

(Refer Slide Time: 06:59)



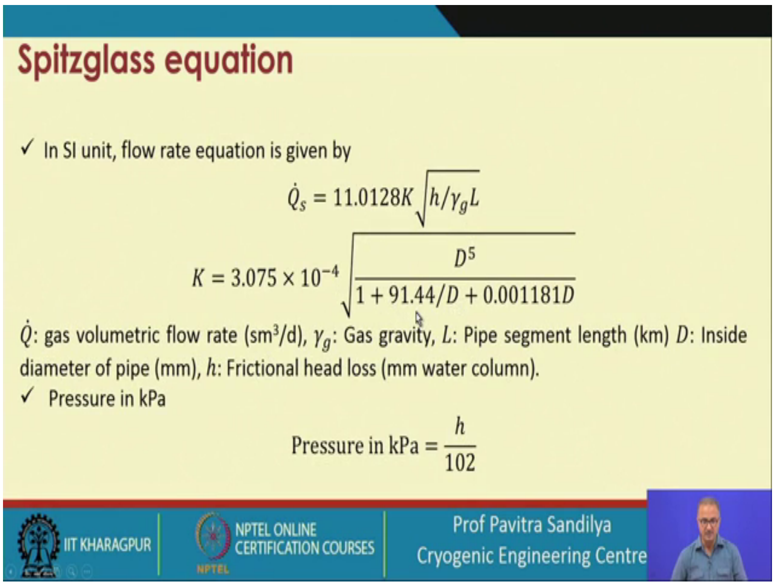
And then this is this Weymouth equation for the SI units again we find that the values of these coefficients have, undergone some changes.

(Refer Slide Time: 07:11)



There is another equation that is the Spitzglass equation and this is generally, used for low pressure line in the, sorry this whenever a compressed air, low pressure lines will be there. So, this is the expression for the Spitzglass equation and in this case we find that we have this h is the Frictional head loss in inches of water column and this is the Gas gravity and the value of the K is given in terms of the inside diameter of the pipe line.

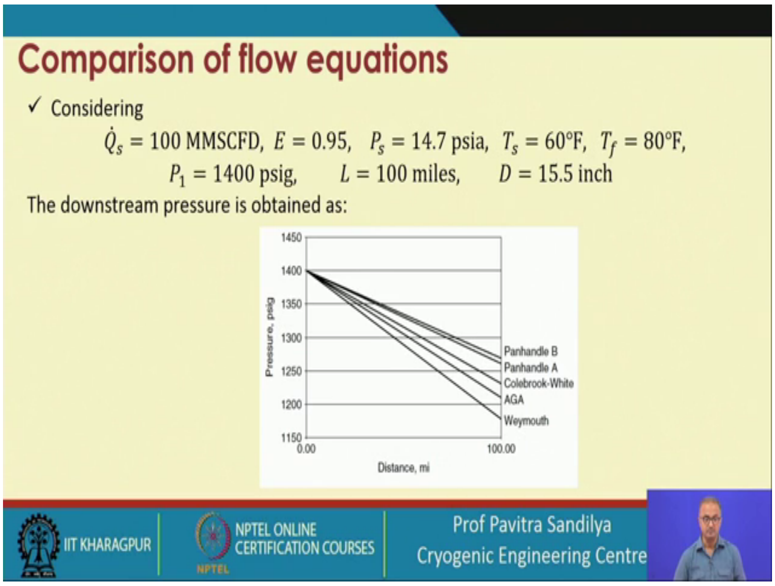
(Refer Slide Time: 07:42)



And the similar expression is given for the SI units again you see that this particular value and these coefficient values have changed for the, different types of units and. So, has the value of this particular a coefficient.

So, and this is if, we find the value of this, h in terms of the kilopascal it can be derived that h this is the, this h in terms of millimeters of water column and then this is by dividing by 102; we get the value of the, in terms of the kilopascal. So, we can also convert this, kilopascal if you are giving kilopascal you can convert it into, terms of the, water column, or vice versa.

(Refer Slide Time: 08:22)



Now, whenever, we have So many equations we does., the question comes that how to choose the right expression for our system and, we can have a look at these, predictions of the say downstream pressure by taking some typical values and see that how the various types of equations are predicting the values. So, here to compare this what we have done that we have taken a standard, volumetric flow rate to be 100 million standard cubic feet per day, the efficiency factor we, took to be is 95 percent then the P s standard pressure is 14.7 psia that is about one atmosphere and this is taking a 16 degree Fahrenheit that is about 15.6 degree centigrade. The actual temperature is taken to be 80 degree Fahrenheit this is the, actual pressure at the inlet site that is 1400 psig and the length of the pipeline is 100 miles and D is the diameter in centimeter pipe is 15.5 inches.

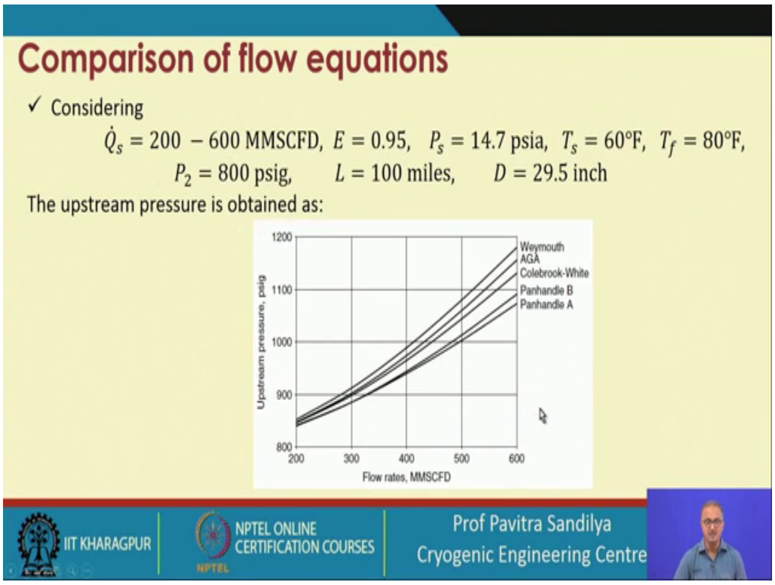
Now, please understand the unit pressure has been given in terms of the, gauge pressure. So, before you, use any of the expressions to find out the flow rate or the friction factor you have to first convert this gauge pressure into the absolute pressure and in this case you simply add 14.7 that is the ambient pressure to this particular pressure and get the absolute pressure. Now, once you put the absolute pressure you can use those, various expressions to find out the downstream pressure.

Now, you can see that, depending on the distance that how the downstream pressure is changing. So, it has been done over a distance of 0 to 100 mile and what we find that initially all of them are starting from the same value and for small distances the predictions are almost similar. So, for we find that over a small distance, it does not matter which type of expressions we are using, but as the distance keeps increasing we find that there are some changes in the values of the downstream pressure that is the frictional loss in the pipelines are calculated, differently by the different expressions.

And in this case we find that the prediction or the Panhandle B is, the highest and the Weymouth is lowest. So, that means, Weymouth is giving me the maximum pressure drop and the Panhandle B is giving the minimum pressure drop among these various expression and what it means? It means that if, we are using the Weymouth equation then we shall be having a compressor which will be which should be giving me the very high which can handle very high pressure drops.

So, in a way that Weymouth equation is giving me very conservative estimate of the pressure drop because, we will needing a higher capacity compressor or higher, compressor which can handle, more delta P which can give us more pressure ratio that kind of compressor we shall be using if you are using the Weymouth equation.

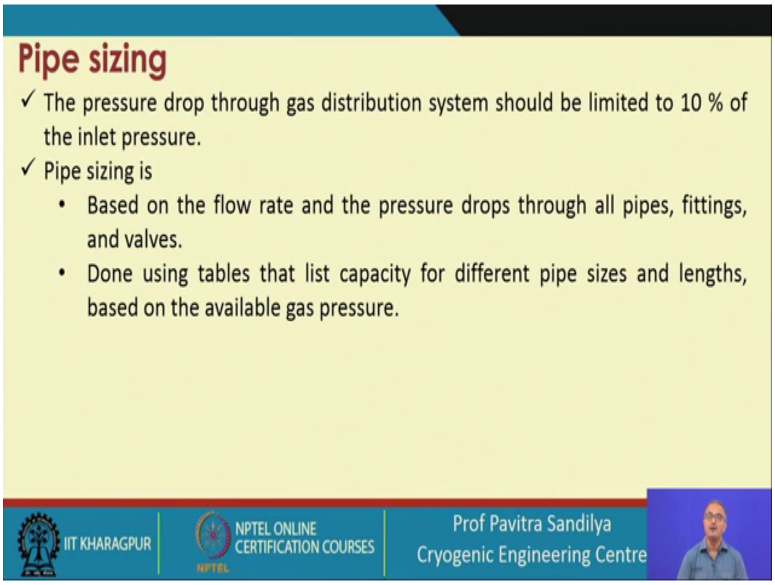
(Refer Slide Time: 11:30)



Now, in a similar manner what we can see, that we can also find out the other way; that means, now in this case we are given the, outlet pressure, and from that we are, we want to know what is the inlet pressure. So, in this again we find that so, this is the, range of the flow rates and now we are putting in terms of flow rate and length is taken to be a constant and this is some other diameter of the pipeline, and again the pipeline efficiency is taken to be 95 percent.

Now, in this case again we are using the different types of expressions and again we find that Panhandle A is giving the lowest whereas, Weymouth is giving the highest. So, in both the cases wherever, whether we are you are trying to find out the inlet pressure from the given outlet pressure or outlet pressure from the given inlet pressure; the Weymouth equation is always giving us the highest pressure drop that is the most conservative estimate and it is always good that we take some conservative estimate to design or to choose the compressor. So, generally we may take the Weymouth equation to, have the compressor.

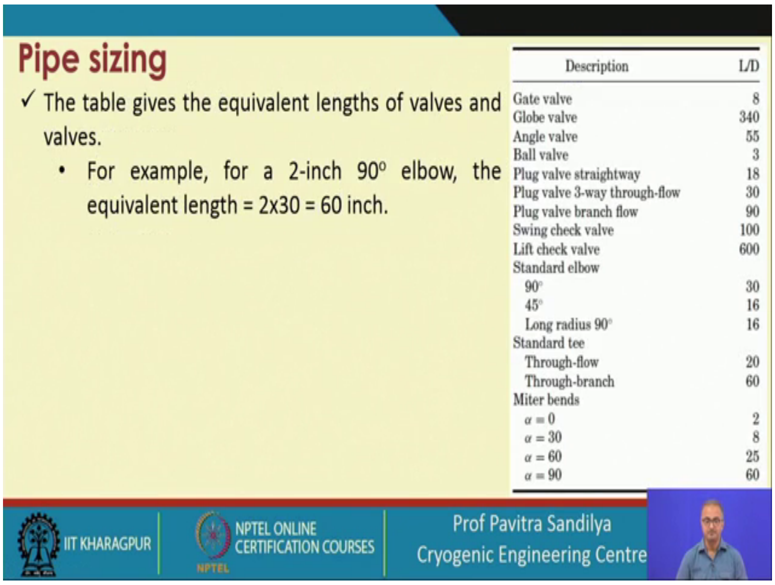
(Refer Slide Time: 12:38)



Now, after knowing these, pressure drops we go to the Pipe sizing and this Pipe sizing what we mean that we have to decide that what kind of diameters, of the pipeline to choose, for a given length. So, this pressure drop to the, gas distribution system should be immediately about 10 percent of the inlet pressure. So, this is a kind of a thumb rule we follow to design the pipe, pipe size to design the pipelines.

So, we do not want to exceed 10 percent of the inlet pressure; that means, if the suppose the inlet pressure is say 1000 bar or, 800 bar. So, we will not like to have the 10 percent of the that is we do not want to have more than 100 bar of pressure drop inside the pipe ok, and the pipe sizing is, Based on the flow rate and pressure drops to all the pipes fittings and valves and this is Done using some table, that list capacity of different pipe sizes and lengths based on the available gas pressure. So, these are the ways to find out the size of the pipe.

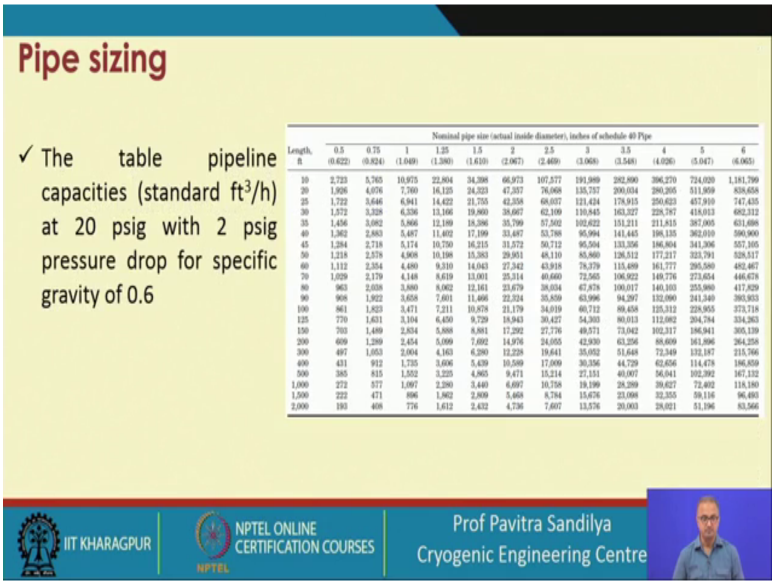
(Refer Slide Time: 13:44)



Now, here we find that to, the table gives us equivalent lengths of valves. So, you see that, we have Gate valve, Globe valve, Angles valve and various types of valves and then we have the some types of fittings. So, we depending on the type of, valve or, fitting we choose we have some equivalent to the straight length ok.

Now, For example, a 2-inch 90 degree elbow 2 inch; that means, we go to the a elbow type of joint and we find there is a elbow and the 90 degree. So, we find the equivalent length is 30. So, that L by D ratio is 30. So, we take this L by D ratio is 30 and because 2 inch we multiply by 2 inch. So, we get the equivalent length to be 60 inch; that means, a 90 degree standard elbow is the kind of pressure drop it will give is equivalent to a straight pipe line of the same material of 60 inch length.

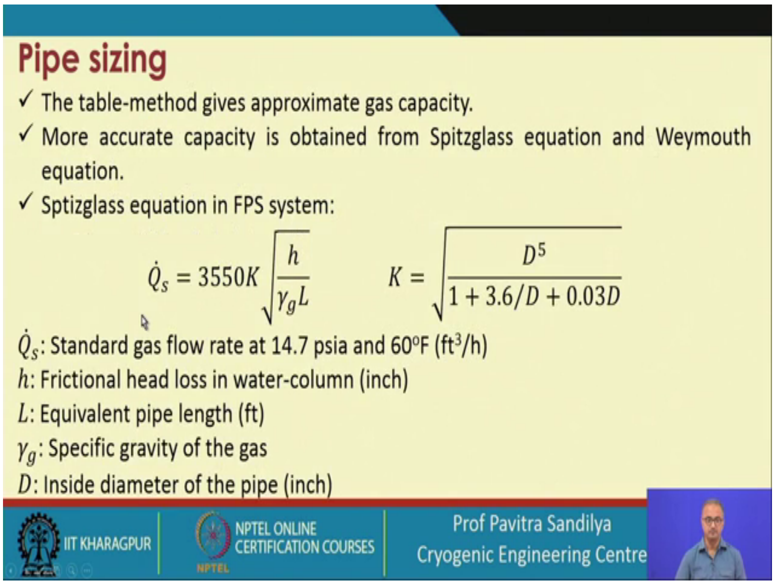
(Refer Slide Time: 14:37)



Now, in this particular table what you find that we have been given the various types of length and a nominal pipe sizes and we find that the, capacities in the pipeline has been given. So, here we find that, this is, and you will find this kind of table is given for different types of pipe line and here this is for the nominal pipe sizes the, and in this particular bracket we have been given in the inside diameter and this is the inches of schedule 40 pipe schedule 40 this schedule number signifies the thickness of the pipe line and the from the nominal diameter we have for different nominal diameters we are given difference of the outside diameter and the schedule number gives the thickness of the pipe line. So, with these 2, knowledge we can find out the inside diameter of the pipe line.

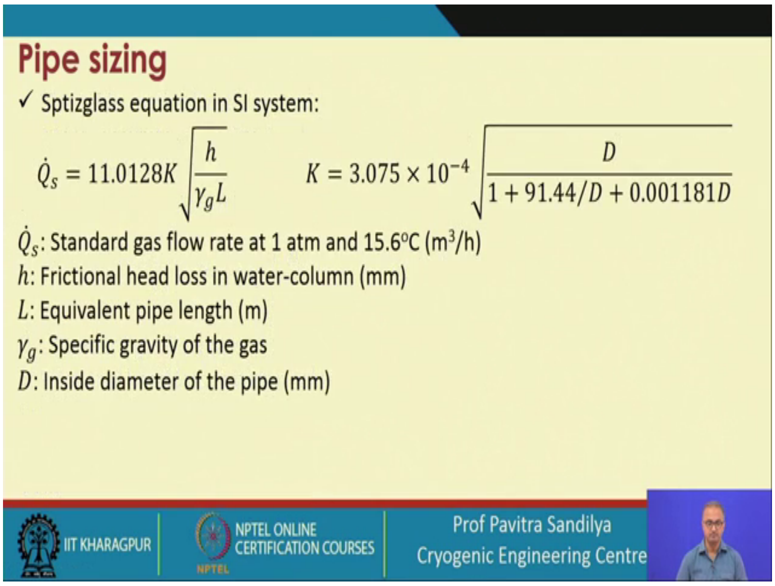
So, here we find this 0.5, 0.751etcetera they are giving, number of pipe size and it is in calculated for the particular schedule number the calculated the this bracket you can find the, inside diameter of the, pipeline. So, we find that these are the capacities for this particular that is you can read it like this that if we have a pipeline of 0.5 a nominal diameter and this 40 schedule is 40 then for the pipe length of this. So, this is the capacity of this is given in terms of standard cubic feet per hour this is the capacity of the pipeline. So, this is how we can find out, the allowable capacity in various types of pipe sizes, and also planes the capacity depends on the specific gravity this has been given for a value of 0.6.

(Refer Slide Time: 16:17)



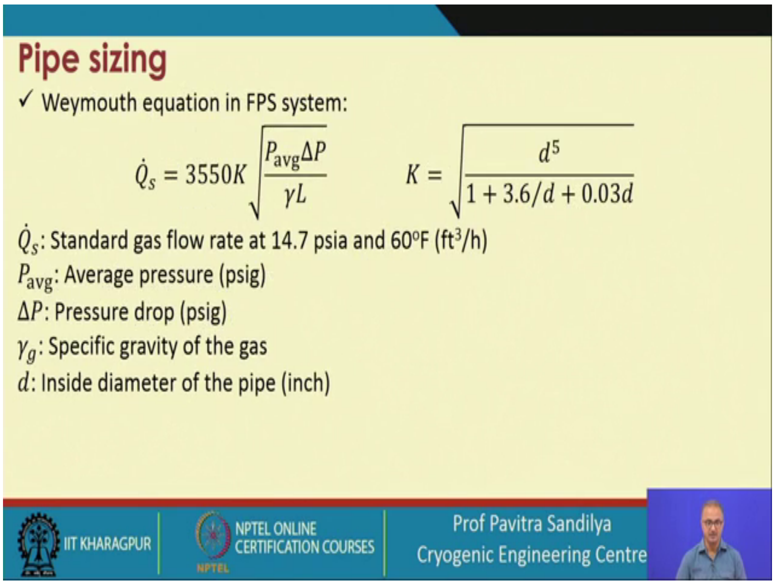
Now, this table gives some approximate gas capacity and more accurate capacities obtained by Spitzglass of Weymouth equation which we have given and this is again the Spitzglass expression for the FPS systems, which I have already mentioned. So, you can find out this, you can use this Spitzglass equation to, find out the actual capacity in the pipeline.

(Refer Slide Time: 16:43)



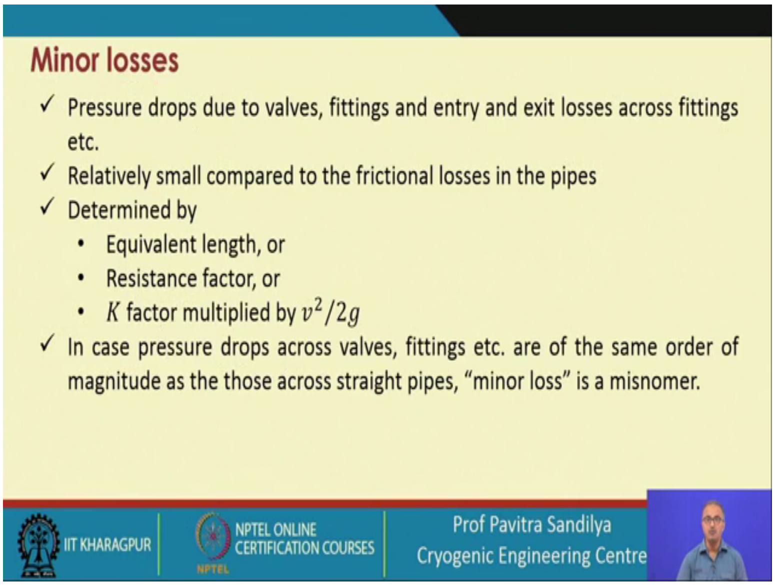
So, this is in the SI unit the same Spitzglass, expression which I have shown earlier.

(Refer Slide Time: 16:50)



And this is the Weymouth equation to find out the capacity and this as we said that the Weymouth equation is used for higher, flow rate and the Spitzglass of lower flow rate. And this is for the FPS system and this is for the SI system of unit.

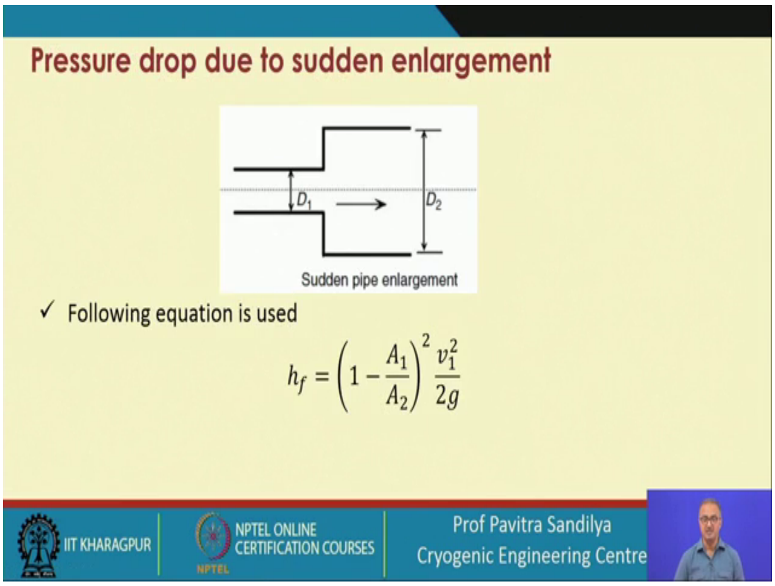
(Refer Slide Time: 17:09)



And now, we come to, the Minor losses and as I told you when I say Minor loss Minor loss does not mean that their magnitudes are less than the Major loss, but the name has been given to differentiate them from the actual pipe length. So, here we have the valves fittings entry and exit losses across the fittings etcetera; and relatively small compared to frictional losses inside the pipe lines why because they are not used. So, rampantly as we use the long pipeline we want to have as long pipeline as possible, but in between we need for control purpose and sometimes your pipeline do not comes in the, finite length. So, we need to join the pipelines. So, that is and we also sometimes we need to change the direction of the flow. So, for this we only need the fittings and the valves. So, these are not coming in a very large quantity

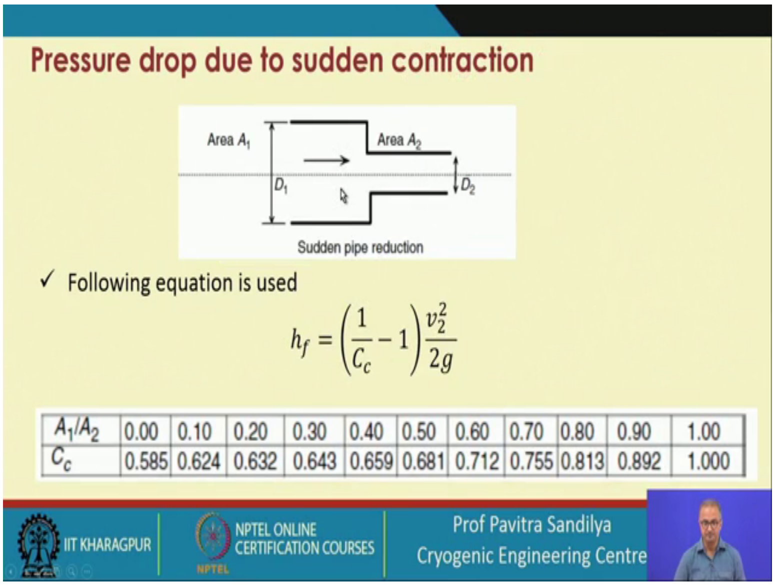
So, that is why the total pressure drop offered by these fittings and valves do not generally match with the pressure drop we find across the whole a straight pipeline system. And they may be determined in the various manner the kind of pressure drop we have, sometimes we can use equivalent range. So, Resistance factor or some K factor and we shall see that if sometimes the total pressure drop offered by these fittings and these pipe, valves may exceed or may become equivalent to the major losses then in that case this minor loss seems to be a misnomer that is it is wrongly said as "minor loss".

(Refer Slide Time: 18:40)



But the name sticks now, here we just take a few examples we have just shown you that how to find out the equivalent length for some of the valves and fittings and here we find out how to find out the head loss in a sudden enlargement and this is the expression for the head loss in sudden enlargement sudden means, that you see that abruptly the, this one pipe line diameter and this is another diameter suddenly that, diameter changes from D 1to D 2 and this A 1 A 2 means, A 1 is pi by 4 D 1 square and A 2 is pi by 4 D 2 square, and this v one is the velocity at this particular thing that is v 1 is equal to Q dot that is Volumetric flow rate divided by A 1 ok. So, from that we can find the v 1. So, this is how we find the, head loss in this case of sudden enlargement.

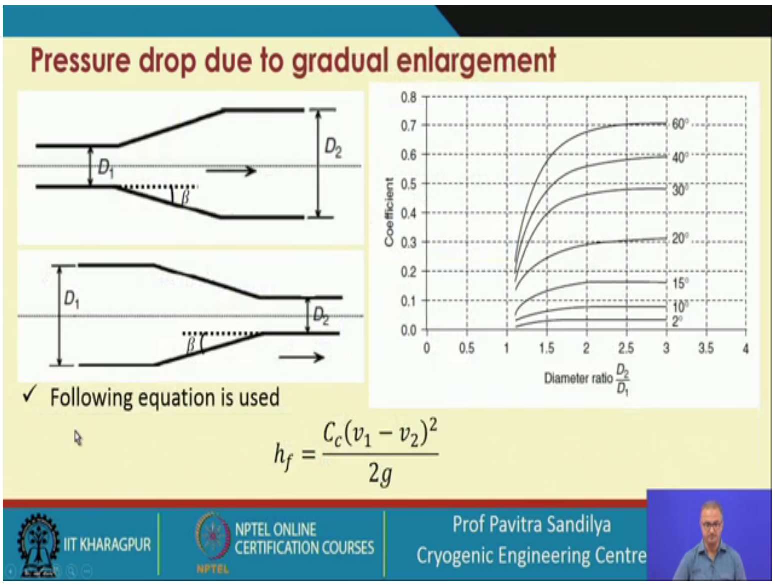
(Refer Slide Time: 19:33)



And now, we have certain contraction now, here you are see that here the initial (Refer time: 19:39) D 1 and it is contracting suddenly entry abruptly to another cross section that is having a diameter of D 2.Now in this case we have a slightly improve means, modified expression and this is, in terms of C c and this is a contraction loss contraction coefficient ok, and this contraction coefficient depends on the ratio of the A 1 and A 2 that is this cross sectional area divided by this area of cross section. So, this if I know this, area ratio then we can find the various values of the contraction coefficient.

And we find that when A 1 is equal to A 2 then, we find that this is equal to 1 that is expected that; that means, there will not be any kind of loss. So, this is the expression; that means this is A 1 and h h f becomes 0 ok. So, that is expected. So, that is why we find that by A 1 by A 2 it is 1 and for 0 it is the lowest value that is we are getting, the high that is the less the cc value the moles will be the value of the hf. So, we are getting the lowest value for C c for, when A 1 by A 2 is 0, ok. Of course, 0 is something, means a, extreme case we do not get, 0, generally and, this, one thing you must understand this that in this case A 1 A 2 this A 1 in this expression is given to be more than, A 2. So, I, it should be rather A 2 by A 1 not A 1 by A 2 it should be A 2 by A 1; because this A 1 by A 2 will be more than 1. So, this is a small correction we have to make here.

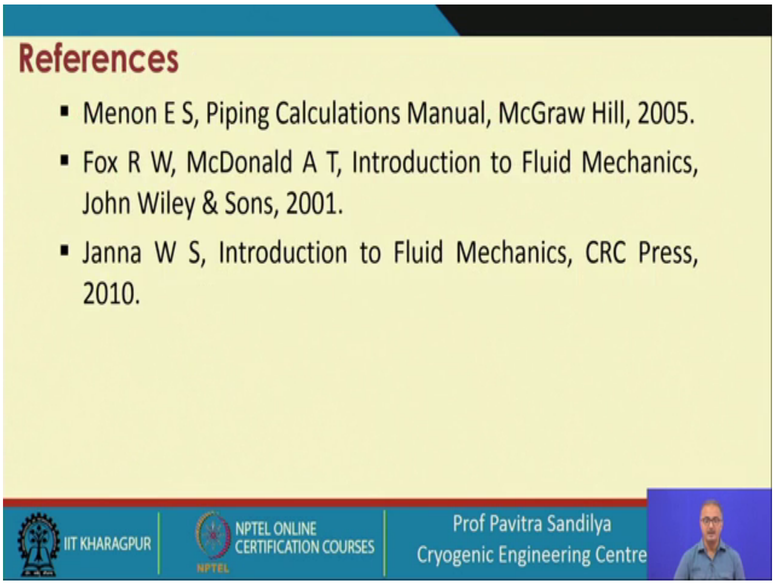
(Refer Slide Time: 21:15)



Now, we have the; cases of gradual, enlargement and gradual contraction, you see that because of this, particular, length we are providing to gradually decrease the cross section or increase the cross section and whenever it is gradual the Pressure drop will be less abruptness, gives higher Pressure drop gradual gives lower, because the Pressure recovery we say the Pressure recovery is more, when the, area of cross section changes gradually, and he will here we find the expression, for both the cases this is the expression for the, for the head loss and here this coefficient cc is found from this particular thing and here you will find that this 2 degree 10 degree 15 degree these are the beta values here

So, depending on this value of this particular, angle we find that we have different values of the coefficient and for a given diameter ratio we find this coefficient values e is largest when the beta value is largest. It means that, the, it means that the, the more this, angle we are providing the more is the head loss, that is the steepest the (Refer time: 22:33) becomes steep it is goal goes towards the, abrupt change.

(Refer Slide Time: 22:39)



And these are the various, References you may refer to, to find out detail about this particular, this friction etcetera friction factor and the pressure drop etcetera.

Thank you.