Chemical Process Utilities
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Lecture – 40
Design of Pipeline - Natural Gas Transmission

Welcome to the design of pipelines and in this particular chapter, we are going to discuss about the natural gas transmission. Let us have a brief outlook about what we discussed in the previous lecture. We discussed about the natural gas transmission. We derived the general flow equation in steady state with respect to the kinetic energy term, with respect to the pressure energy term, potential energy term and friction loss term.

In this particular lecture, we are going to discuss about the various flow regimes including fully turbulent flow that is rough pipe flow, partially turbulent flow that is smooth pipe flow, pressure drop calculation. We will discuss the pipelines in series, pipelines in parallel, pipeline in segmental looping.

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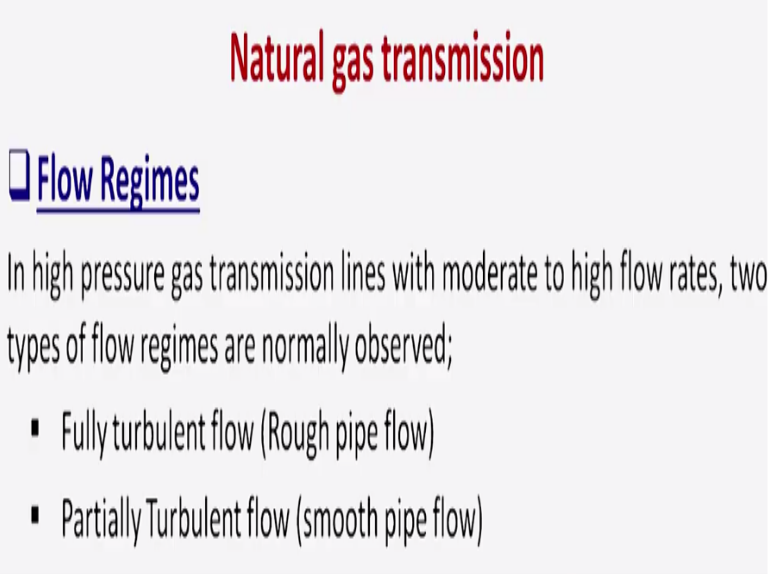

Now, let us talk about the flow regimes. Now, in high pressure gas transmission lines with moderate to high flow rates, there are two types of flow regimes which are normally observed. One is the fully turbulent flow that is rough pipe flow and second one is the partially turbulent flow. So, the regime of flow is defined by the Reynolds number which is dimensionless and Reynolds number is Re = rho D u over mu.

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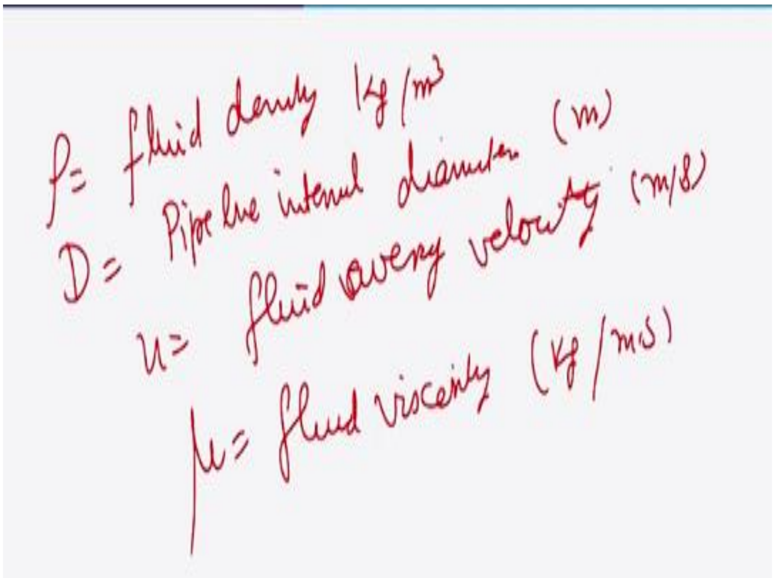
The regime of the flow is defined by Reynolds number (Dimensionless);

$$Re = \frac{\rho . D . u}{\mu}$$



Now, here if you see that the term used in the Reynolds number that is rho is equal to fluid density in kilogram per meter cube, D is the pipe diameter or the pipeline internal diameter m, u is the fluid average velocity in meters per second and mu is the fluid viscosity that is kilogram per meter second.

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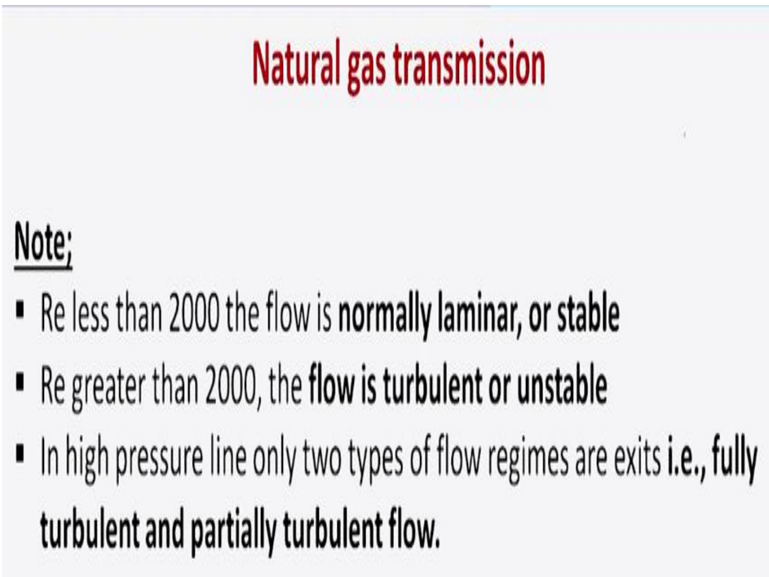

Now, if Reynolds number is less than 2000, the flow is normally laminar or stable. Now, if Re is greater than 2000, the flow is turbulent or unstable. In high pressure line only two type of flow regimes they are exist, fully turbulent or partially turbulent flow.

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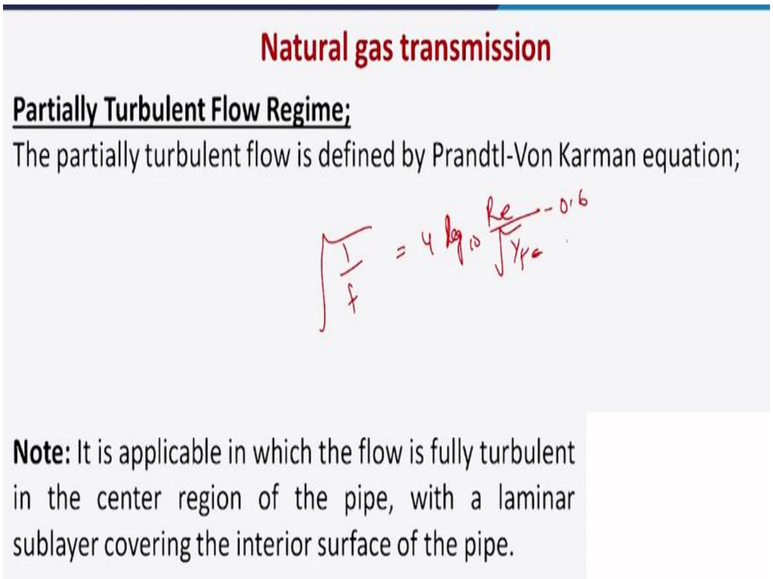

Now, let us talk about the partially turbulent flow regime. The partially turbulent flow is defined by the Prandtl-Von Karman equation and this equation is square root of 1 upon f = 4 log to the base 10 Re upon 1 upon f – 0.6 where f is the friction factor re dimensionless and Re is the Reynolds number. Now, it is applicable in which the flow is fully turbulent in the centre region of the pipe with a laminar sublayer covering the interior surface of the pipe.

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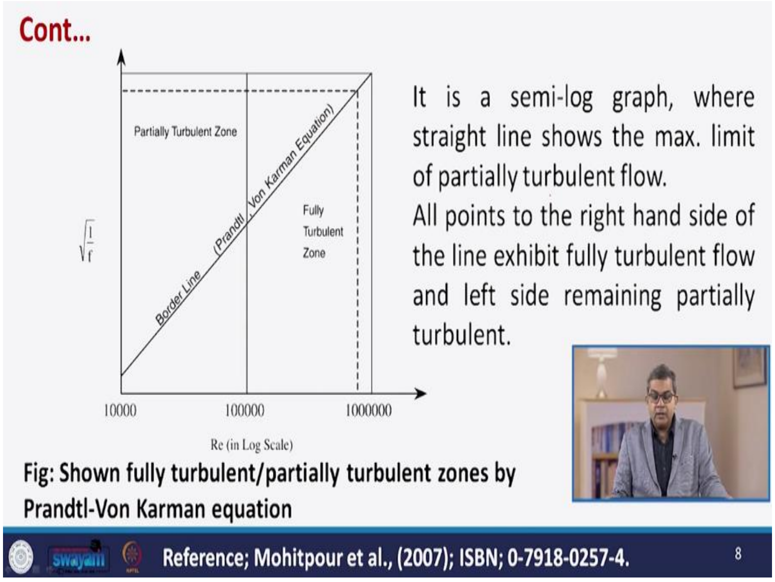
<u>Partially Turbulent Flow Regime;</u>

The partially turbulent flow is defined by Prandtl-Von Karman equation;

$$\sqrt{\frac{1}{f}} = 4\log_{10}\frac{Re}{\sqrt{\frac{1}{f}}} - 0.6$$

Where, f = friction factor (dimensionless), Re = Reynolds Number (dimensionless)



Now, here you can you see that it is a semi-log graph where the straight line shows the maximum limit of partial turbulent flow. Now, all points to the right hand side of the line this exhibit fully turbulent flow and left hand side remain partially turbulent. This is a fully turbulent, partially turbulent zones by Prandtl-Von Karman equation.

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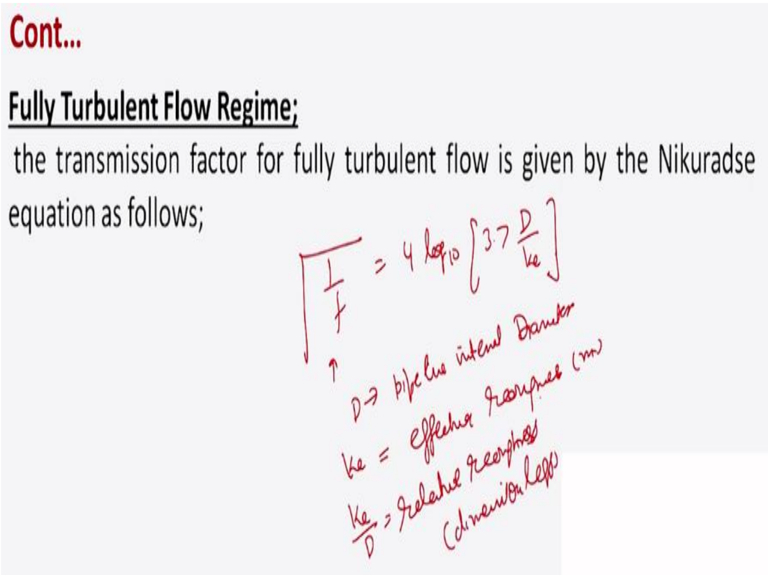

Let us talk about fully turbulent flow regime. The transmission factor for fully turbulent fluid is given by Nikuradse equation which is as represented 1 upon f = 4 log to the base 10 3.7 D upon K e, where 1 upon f this is the transmission factor which is dimensionless in nature, D is the pipeline internal diameter, K e is the effective roughness that is represented in m and K e upon D is the relative roughness that is dimensionless.

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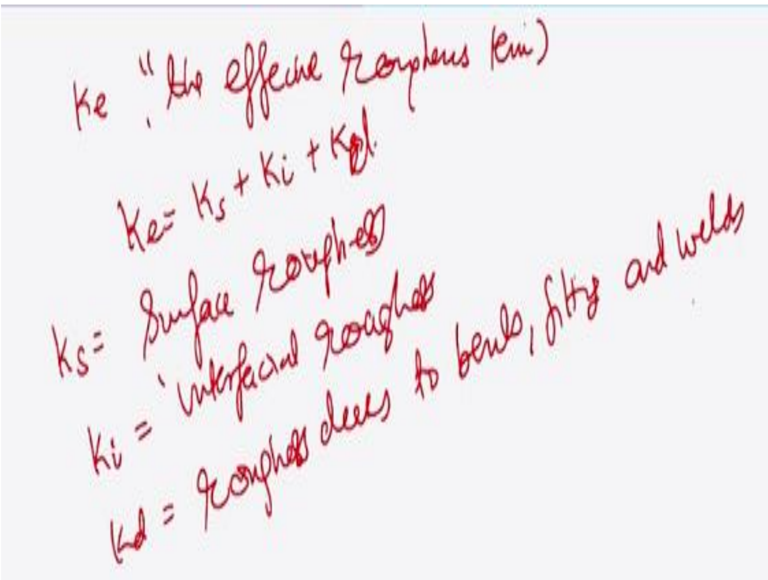
Fully Turbulent Flow Regime;

the transmission factor for fully turbulent flow is given by the Nikuradse equation as follows;

$$\sqrt{\frac{1}{f}} = 4\log_{10}\left[3.7\frac{D}{K_e}\right]$$



Now, this K e the effective roughness term this can be defined as K e = K s + K i + K d now where K s is the surface roughness, K i is the interfacial roughness and K d is equal to roughness due to bend, fitting sometimes they are very common and wells. Now, with high pressure gas transmission lines with high flow rate and fully turbulent flow regime and natural gas is almost dry and K d and K i are negligible if you compare with the K s.

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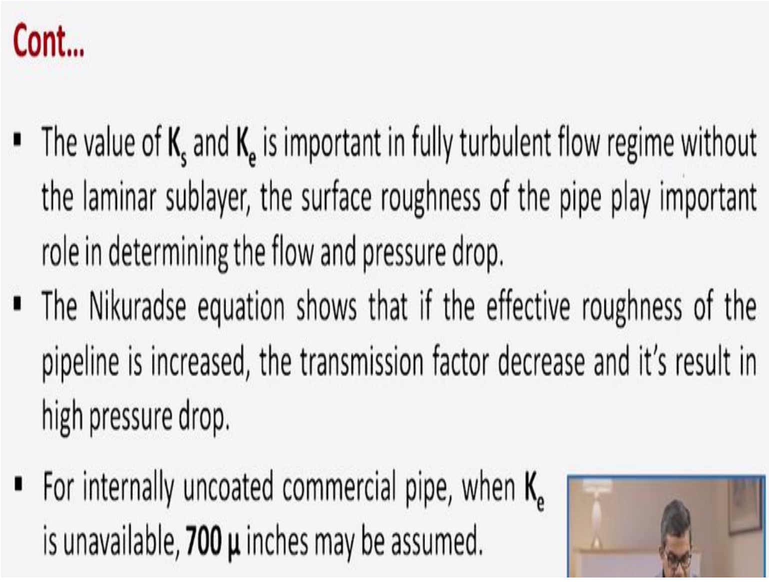
K_e **"the effective roughness term" can be defined as;**

$$K_e = K_s + K_i + K_d$$



Now, the values of K s and K e is very important in fully turbulent flow regime without the laminar sublayer, the surface roughness of the pipe play an important role in determining the flow and pressure drop. The Nikuradse equation shows that if the effective roughness of the pipeline is increased the transmission factor decrease and its result in high pressure drop. So, for internally uncoated commercial pipe where this K e is unavailable 700 microns inch maybe assumed.

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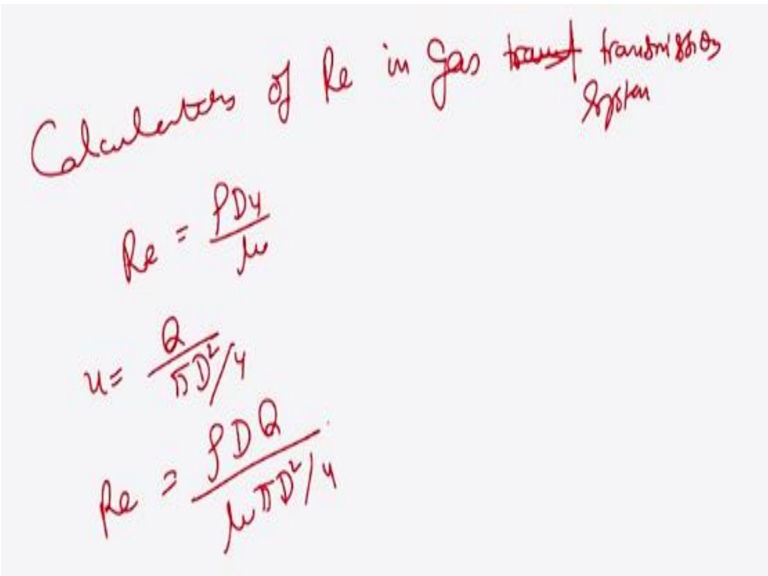

Now, the calculation of Reynolds number in gas transmission system, Re in gas transmission system, so this Re = rho D u upon mu, u = Q upon pi D square by 4 where Re = rho D Q upon mu pi D square by 4.

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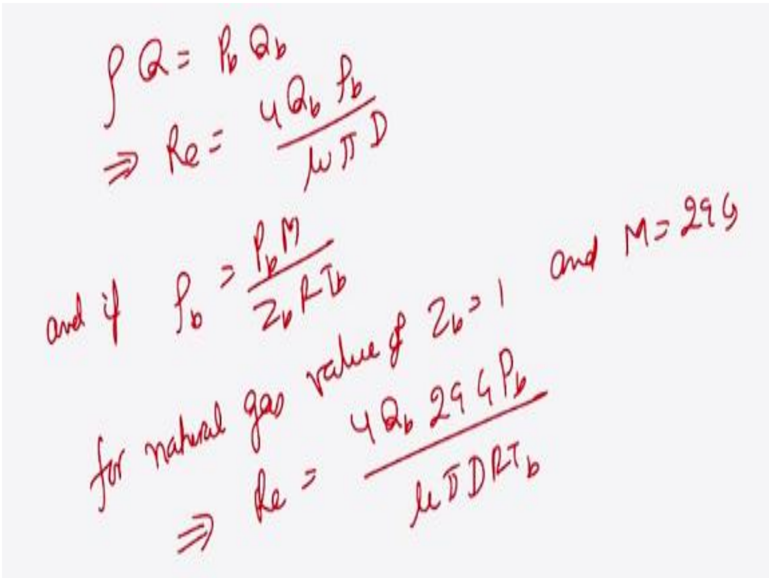
We know that Reynolds number can be defined as; $$Re = \frac{\rho. D. u}{\mu}$$

Where, $$u = \frac{Q}{\pi D^2/4}$$

Therefore; $$Re = \frac{\rho. D. Q}{\mu. \pi D^2/4}$$



Now, at steady state condition rho Q = P b Q b, this is the Reynolds number = 4 Q b rho b upon mu pi D and if rho b = P b M upon Z b R T b. For natural gas value of Z b = 1 and M = 29 G. So, Re = 4 b 29 G P b upon mu pi D R T b.

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At steady-state condition;

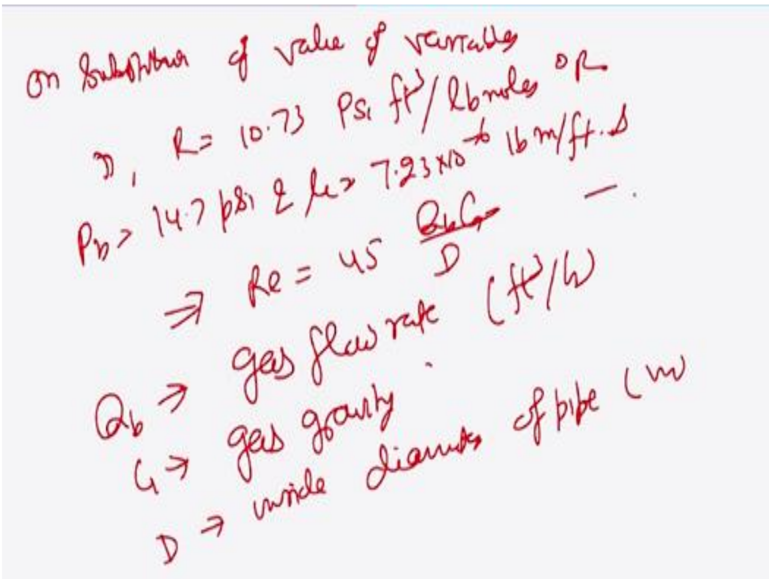
$$\rho Q = \rho_b Q_b$$

$$\Rightarrow Re = \frac{4Q_b. \rho_b}{\mu \pi D}$$

And if, $$\rho_b = \frac{P_b. M}{Z_b. R. T_b}$$

For, Natural gas the value of Z_b=**1** and **M= 29G**;

$$\Rightarrow Re = \frac{4Q_b.29G. P_b}{\mu. \pi. D. R. T_b}$$



So, on substitution of value of variables pi Re = 10.73 psi cubic feet per ton moles R, P b = 14.7 psi, mu = 7.23 into 10 to the power –6 pound metre per second, the Re = 45 Q b G upon D. Now Q b is equal to gas flow rate in cubic feet per hour, G is equal to gas gravity that is dimensionless, D is inside diameter of pipe that is in inch. This is the simplified equation and that gives the Reynolds number in terms of pipeline parameters.

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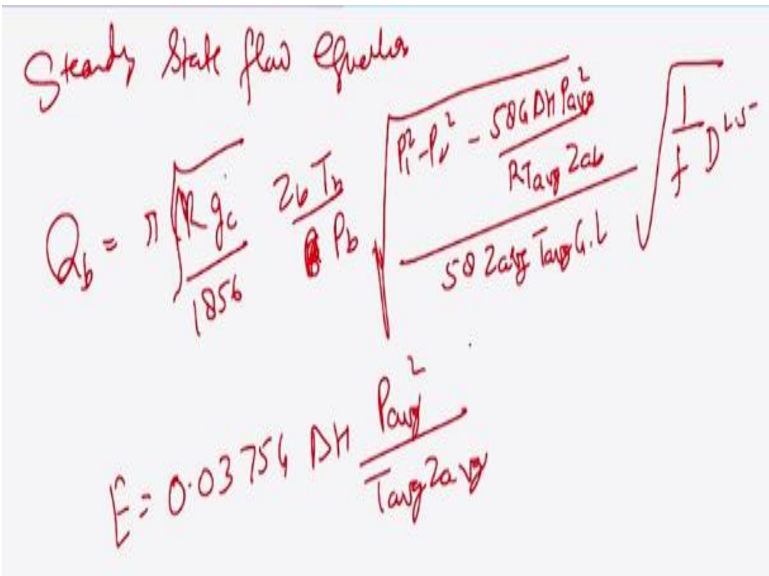
On substitution of the value of variables π, R=10.73 Psi.ft3/lbmoles. ºR, P_b=14.7 Psi, and μ= 7.23x10^{-6} lb m/ft. s

$$\Rightarrow \boldsymbol{Re = 45\frac{Q_b G}{D}}$$



Now, let us talk about steady state flow equations. So, the general flow equation of natural gas in pipeline is given by Q b = pi R g c upon 1856 Z b T b upon P b P 1 square – P 2 square – 58 G delta H average P square upon R T average Z average upon 58 Z average T average G L 1 upon f D to the power 2.5. Now, assume potential energy turn that is E = 0.0375 G delta H average P upon T average Z average.

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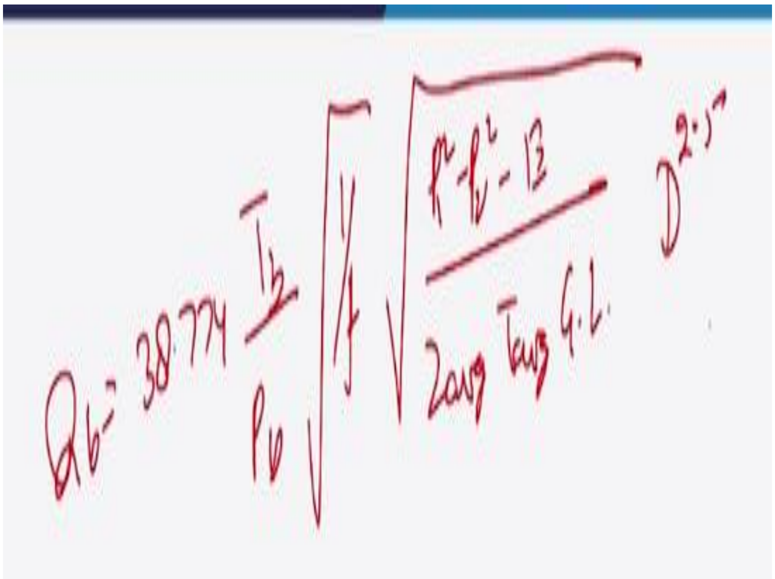
Steady state flow equations;

The general flow equation of natural gas in pipeline is;

$$Q_b = \pi \sqrt{\frac{R.g_c}{1856}}.\frac{Z_b.T_b}{P_b}\sqrt{\frac{P_1^2 - P_2^2 - \frac{58G.\Delta H.P_{avg}^2}{R.T_{avg}.Z_{avg}.}}{58Z_{avg}.T_{avg}.G.L}}.\sqrt{\frac{1}{f}}D^{2.5}$$

Assume, Potential Energy term;

$$E = 0.0375G.\Delta H.\frac{P_{avg}^2}{T_{avg}Z_{avg}}$$



Then on upon simplifying we get Q b = 38.774 T b upon P b 1 upon f P 1 square – P 2 square – E upon Z average T average G L D to the power 2.5. Now, this is the most common and widely used flow equation and that is suitable for design of large diameter high pressure gas transmission line.

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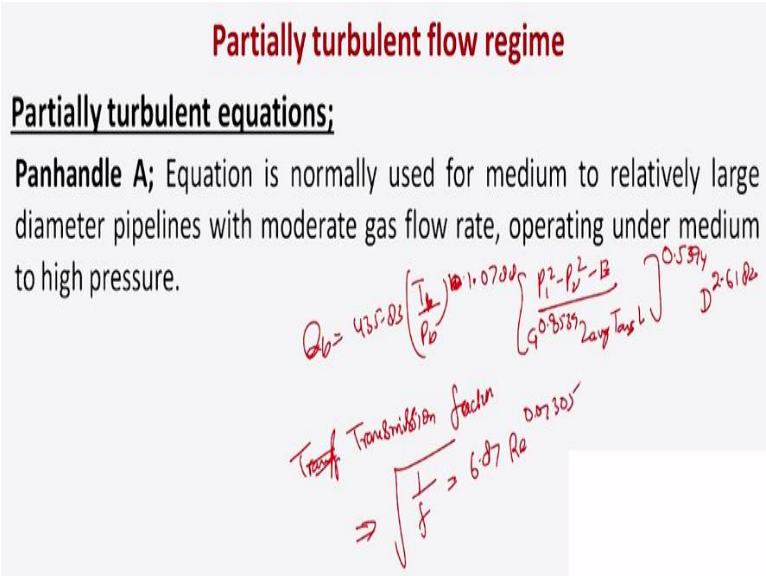
Then, we have on simplifying;

$$Q_b = 38.774\frac{T_b}{P_b}.\sqrt{\frac{1}{f}}.\sqrt{\frac{P_1^2 - P_2^2 - E}{Z_{avg}.T_{avg}.G.L}}D^{2.5} \qquad \text{.....Equation (4)}$$

Note; This is the most common and widely used flow equation that are suitable for design of large diameter, high-pressure gas transmission lines.



Now, let us talk about the partially turbulent equation, Panhandle equation. This equation is normally used for medium to relatively large diameter pipeline with moderate gas flow rate operating under medium to high pressure. Now, here we can see that Q b = 435.83 T b upon P b to the power 1.0788 into P 1 square – P 2 square – E upon G to the power 0.8539 Z average T average L to the power 0.5394 D to the power 2.6182. Now, the transmission factor is defined as 1 upon f 6.87 Re to the power 0.07305.

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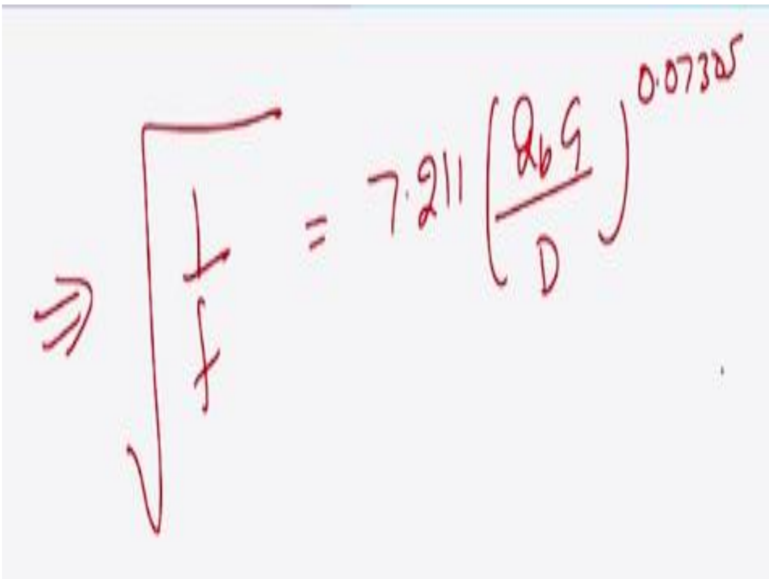
Partially turbulent equations;

Panhandle A; Equation is normally used for medium to relatively large diameter pipelines with moderate gas flow rate, operating under medium to high pressure.

$$Q_b = 435.83\left(\frac{T_b}{P_b}\right)^{1.0788} . \left[\frac{P_1^2 - P_2^2 - E}{G^{0.8539} . Z_{avg} . T_{avg} . L}\right]^{0.5394} . D^{2.6182}$$

Transmission factor is defined as;

$$\Rightarrow \sqrt{\frac{1}{f}} = 6.87Re^{0.07305}$$



Or this can be 1 upon f = 7.211 Q b G upon D to the power 0.07305. Now, we can link all these parameters which we have discussed earlier.

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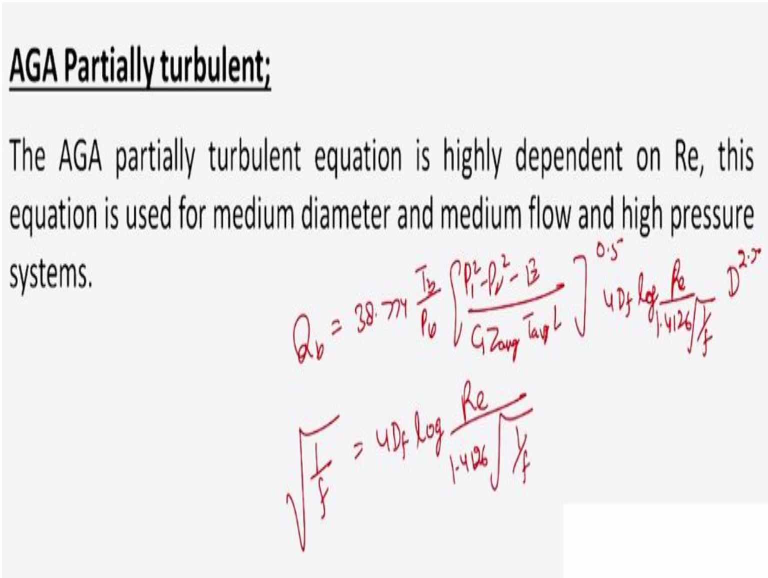
Or,

$$\Rightarrow \sqrt{\frac{\boldsymbol{1}}{\boldsymbol{f}}} = \mathbf{7.211}\left(\frac{\boldsymbol{Q_b.G}}{\boldsymbol{D}}\right)^{\mathbf{0.07305}}$$

<u>Note;</u> All the parameters are as discussed before.



Now, AGA partially turbulent, this AGA partially turbulent equation is highly dependent on Reynolds number. Now this equation is used for medium diameter and medium flow and high pressure system. Now, let us write this particular equation this Q b = 38.774 T b upon p B P 1 square – P 2 square – E upon G Z average T average L to the power 0.5 4 D f log Re upon 1.4126 square root of ‘f’ D 2.5. Now, the transmission factor is defined as 1 upon f = 4 D f log Re upon 1.4126 square root of ‘f’.

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<u>AGA Partially turbulent;</u>

The AGA partially turbulent equation is highly dependent on Re, this equation is used for medium diameter and medium flow and high-pressure systems.

$$Q_b = 38.774\frac{T_b}{P_b}.\left[\frac{P_1^2 - P_2^2 - E}{G.Z_{avg}.T_{avg}.L}\right]^{0.5}.4D_f log\frac{Re}{1.4126\sqrt{\frac{1}{f}}}.D^{2.5}$$

Transmission factor is defined as;

$$\Rightarrow \sqrt{\frac{1}{f}} = 4D_f log\frac{Re}{1.4126\sqrt{\frac{1}{f}}}.$$

Now where D f is drag factor, normally appears in the partially turbulent flow equation and its numerical value is ranging from 0.92 to 0.97.

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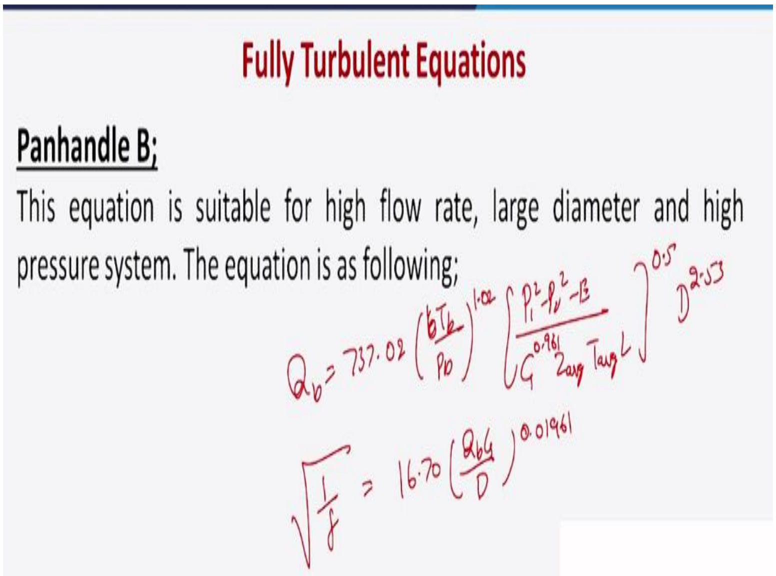
Where,

D_f is drag factor, normally appears in partially turbulent flow equations. Its numerical value in the range from 0.92 to 0.97.



Now, Panhandle B, this equation is suitable for high flow rate, large diameter and high system. Now, this equation can be represented as Q b = 737.02 T b upon P b to the power 1.02 P 1 square – P 2 square – E upon G to the power 0.961 Z average T average L 0.5 D to the power 2.53. The transmission factor is usually defined as 1 upon f = 16.70 Q b G upon D 0.01961.

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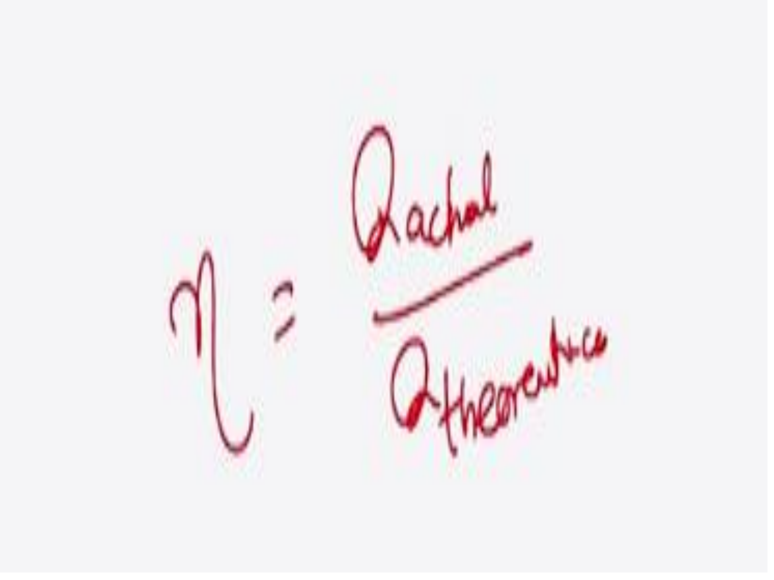
<u>Panhandle B;</u>

This equation is suitable for high flow rate, large diameter and high-pressure system. The equation is as following;

$$Q_b = 737.02 \left(\frac{T_b}{P_b}\right)^{1.02} \left[\frac{P_1^2 - P_2^2 - E}{G^{0.961} Z_{avg}.T_{avg}.L}\right]^{0.5} .D^{2.53}$$

Transmission factor is defined as;

$$\Rightarrow \sqrt{\frac{1}{f}} = 16.70\left(\frac{Q_b G}{D}\right)^{0.01961}$$



Now, the efficiency in Panhandle B equation is defined as Q actual upon Q theoretical. Now, it is multiplied in the equation to calculate more accurate value of Q b and all the parameters in the main equations are same as per which we have discussed.

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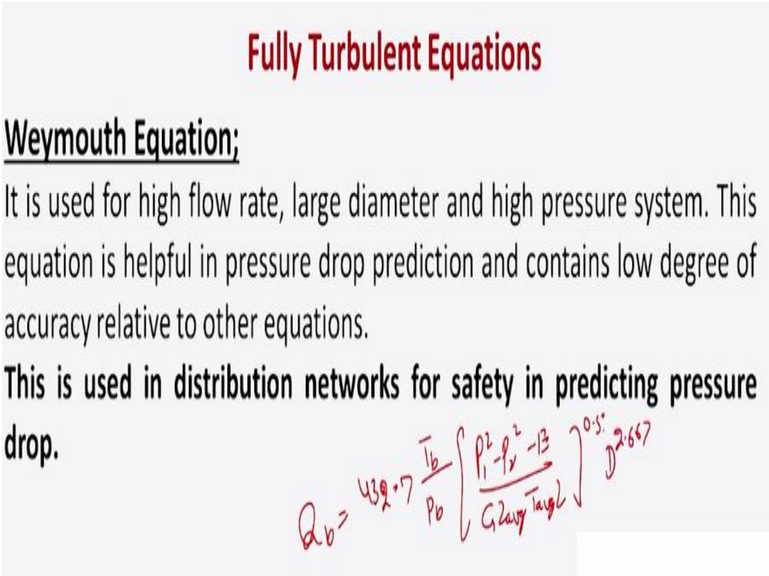
Efficiency in Panhandle B equation is defined as;

$$\eta = \frac{Q_{actual}}{Q_{Theoratical}}$$

It is multiplied in the equation to calculate more accurate value of Q_b and all the parameters in the main equation are same as discussed above.



Now, let us talk about the Weymouth equation. Now, this equation is used for high flow rate, large diameter and large pressure system. This equation is helpful in pressure drop prediction and contains low degree of accuracy relative to other equation. So, this is used in the distribution network for safety in predicting the pressure drop. Now, this equation can be written as Q b = 432.7 T b upon P b P 1 square – P 2 squared – E upon G Z average T average L to the power 0.5 D 2.667.

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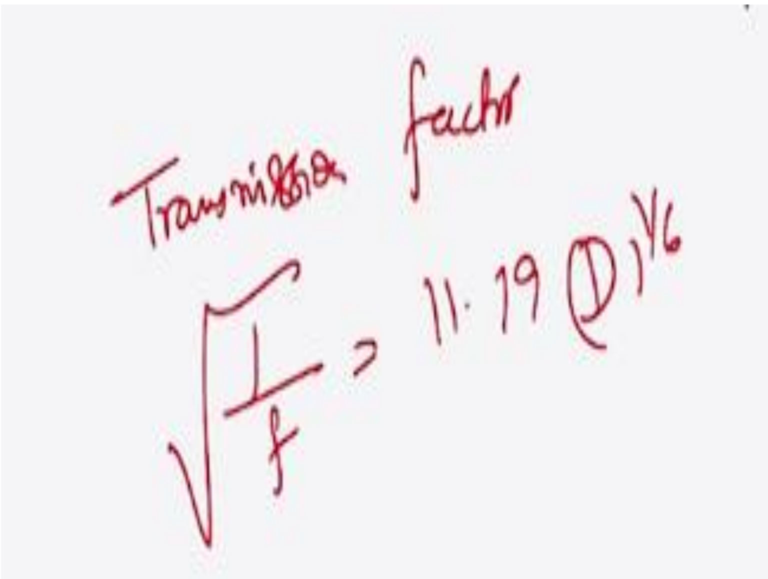
Weymouth equation can be written as:

$$Q_b = 432.7\frac{T_b}{P_b}\left[\frac{P_1^2 - P_2^2 - E}{G.Z_{avg}.T_{avg}.L}\right]^{0.5}.D^{2.667}$$



And the transmission factor can be defined as 1 upon f = 11.19 D to the power 1 by 6.

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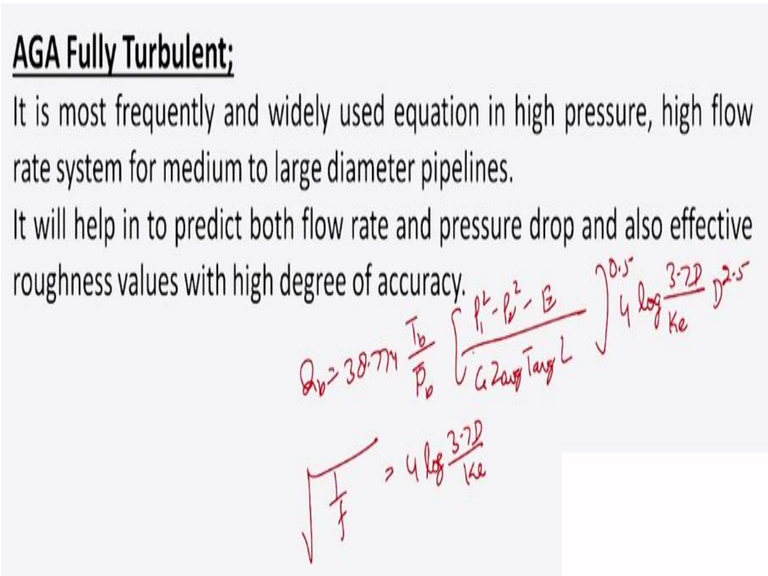
The transmission factor can be defined as;

$$\sqrt{\frac{\mathbf{1}}{\boldsymbol{f}}} = \mathbf{11.19}(\boldsymbol{D})^{\mathbf{1/6}}$$



Now, let us talk about the AGA fully turbulent equation. It is most frequently and widely used equation in high pressure, high flow rate system for medium to large diameter pipelines. It will help in to predict the flow rate and pressure drop and also effective roughness values with a high degree of accuracy. So, this equation is again represented as Q b = 38.774 T b upon P b P

1 is square – P 2 square – E upon G Z average T average L 0.54 log 3.7 D upon K e D to the power 2.5. And the transmission factor can be defined as 1 upon f = 4 log 3.7 D upon K e.

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AGA Fully Turbulent;

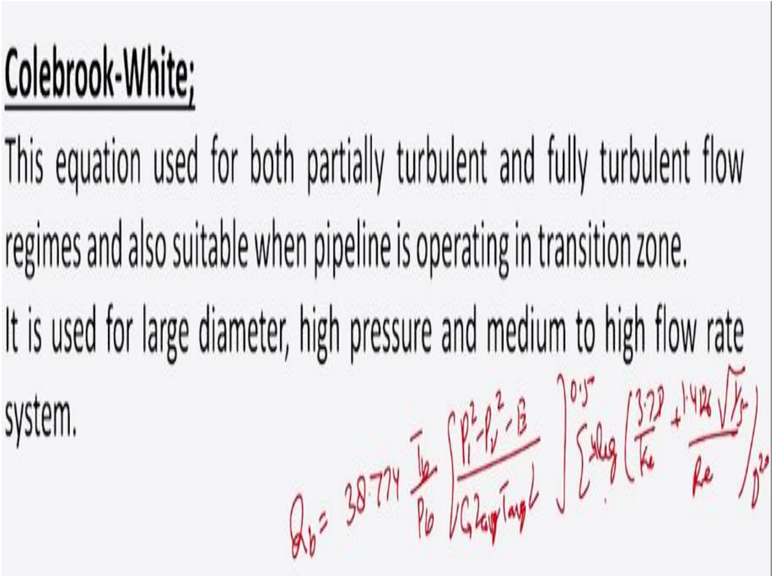
It is most frequently and widely used equation in high pressure, high flow rate system for medium to large diameter pipelines.

It will help in to predict both flow rate and pressure drop and also effective roughness values with high degree of accuracy.

$$Q_b = 38.774\frac{T_b}{P_b}.\left[\frac{P_1^2 - P_2^2 - E}{G.Z_{avg}.T_{avg}.L}\right]^{0.5}.4log\frac{3.7\,D}{K_e}.D^{2.5}$$

The transmission factor can be defined as;

$$\sqrt{\frac{1}{f}} = 4log\frac{3.7D}{K_e}$$



Now, another equation is Colebrook-White. Now, this equation used for both partially turbulent and fully turbulent flow regime and also suitable when pipeline is operating in transition zone. So, it is used for large diameter, high pressure and medium to high flow rate system. Let us write this particular equation Q b = 38.774 T b upon P b P 1 is square – P 2 square – E upon G Z average T average L 0.5 – 4 log 3.7 D K 3 + 1.4126 1 upon f upon Re D to the power 2.5. Now, it predicts a high pressure drop and low flow rates then AGA equation.

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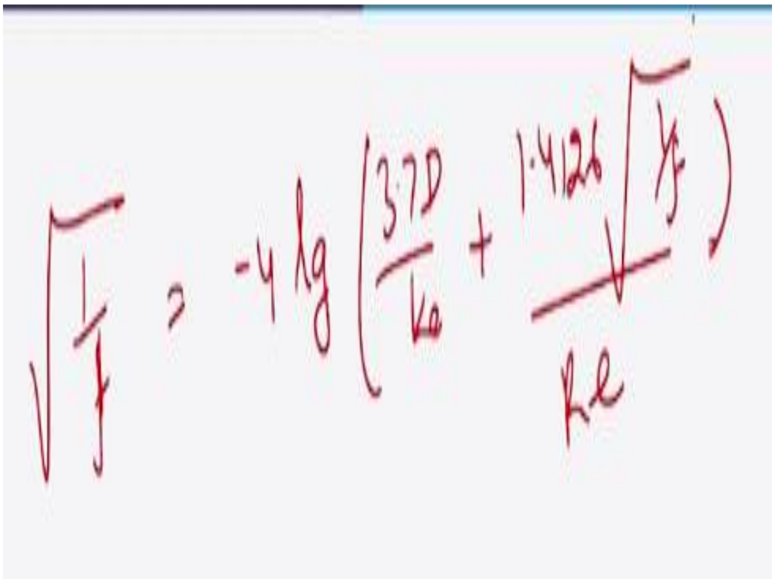
Colebrook-White;

$$\boldsymbol{Q_b = 38.774\frac{T_b}{P_b}.\left[\frac{P_1^2 - P_2^2 - E}{G.Z_{avg}.T_{avg}.L}\right]^{0.5}.[-4log\left(\frac{3.7\,D}{K_e} + \frac{1.4126\sqrt{\frac{1}{f}}}{R_e}\right).D^{2.5}}$$



Now, for this we need to define the transmission factor. So, the transmission factor 1 upon f is defined as –4 log 3.7 D upon K e + 1.4126 1 upon f upon Re.

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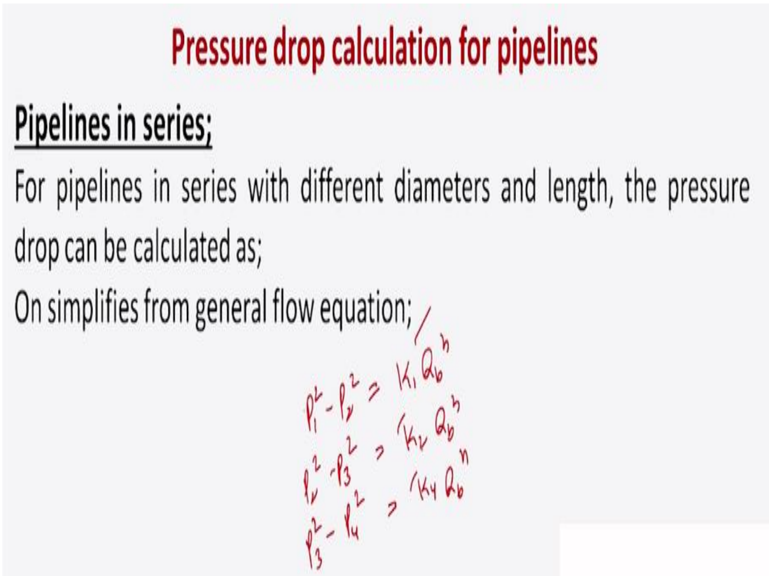
The transmission factor can be defined as;

$$\sqrt{\frac{\boldsymbol{1}}{\boldsymbol{f}}} = -\boldsymbol{4log}\left(\frac{\boldsymbol{3.7\,D}}{\boldsymbol{K_e}} + \frac{\boldsymbol{1.4126}\sqrt{\frac{\boldsymbol{1}}{\boldsymbol{f}}}}{\boldsymbol{R_e}}\right)$$



Now, let us go for the pressure drop calculation for pipelines because pressure drop is very common phenomena in the pipelines. So, there are two cases says, one is the pipeline in series and other one is the pipeline in parallel. So, the pipeline is series with a different diameter and length, the pressure drop can be calculated in a very generalized flow equation like P 1 square – P 2 is square = K 1 Q b n, P 2 square – P 3 square = K 2 Q b to the power n, then P 3 square – P 4 square = K 4 Q b to the power n where K 1, K 2, K 3 these are the pipeline resistance at each segment and n is the flow exponent depending upon the type of equation used.

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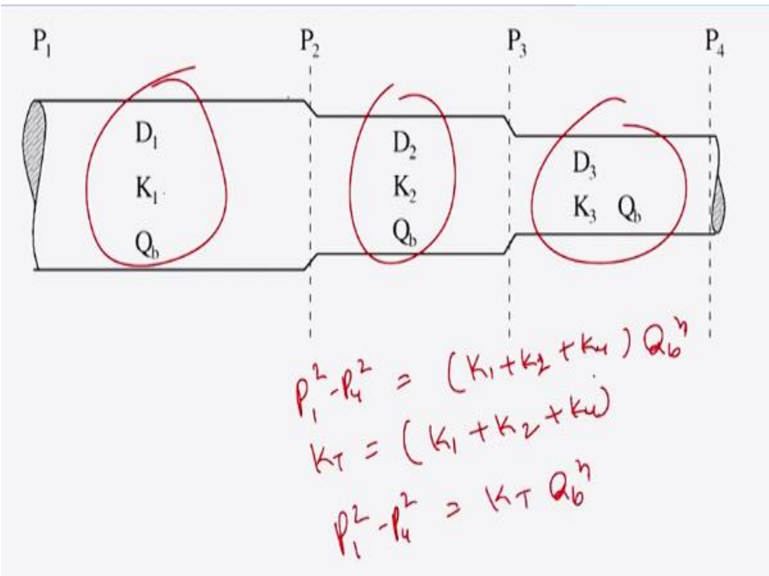
Pipelines in series;

$$P_1^2 - P_2^2 = K_1 Q_b^n$$

$$P_2^2 - P_3^2 = K_2 Q_b^n$$

$$P_3^2 - P_4^2 = K_4 Q_b^n$$

Where, K_1, K_2, and K_3 are pipeline resistance at each segment and n is the flow exponent depending upon the type of equation used.



Now, here we represented this in the form of pictorial diagram. Here the P 1, P 2 and P 3, P 4 these are the pressure regime and D 1, K 1, Q b this is the parameters at this juncture and D 2 that is the diameter K 2 Q b at this juncture and D 3 K 3 to be at this juncture. So, if three equations are added together, then we get P 1 square – P 4 squared = K 1 + K 2 + K 4 Q b to the power n and K T is equal to all K's to be added. So, if we combine these two equations, then we get P 1 square – P 4 square = K T Q b to the power n.

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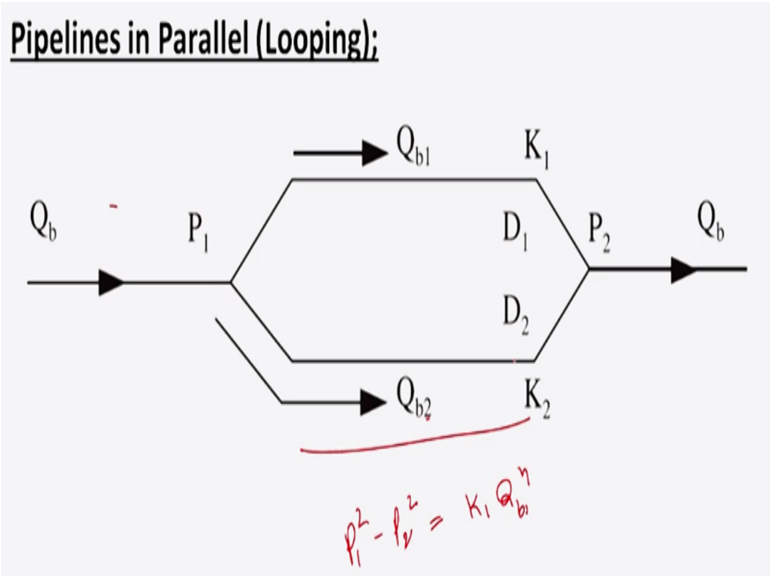
If above three equations are added together, we have;

$$P_1^2 - P_4^2 = (K_1 + K_2 + K_4)Q_b^n$$

Assume, $K_T = (K_1 + K_2 + K_4)$

On combining above equations, we have;

$$P_1^2 - P_4^2 = K_T Q_b^n$$



Now, let us talk about the pipelines in parallel or looping. So, we need to consider the two different pipes are connected in parallel as shown in this figure Q b P 1, Q b 1, Q b 2 and these are the two pipelines K 1 and K 2 D 1 and D 2 and P 2 is the outlet temperature. So, the governing equation for pressure drop for each segment will be represented as P 1 square – P 2 square = K 1 Q b 1 n.

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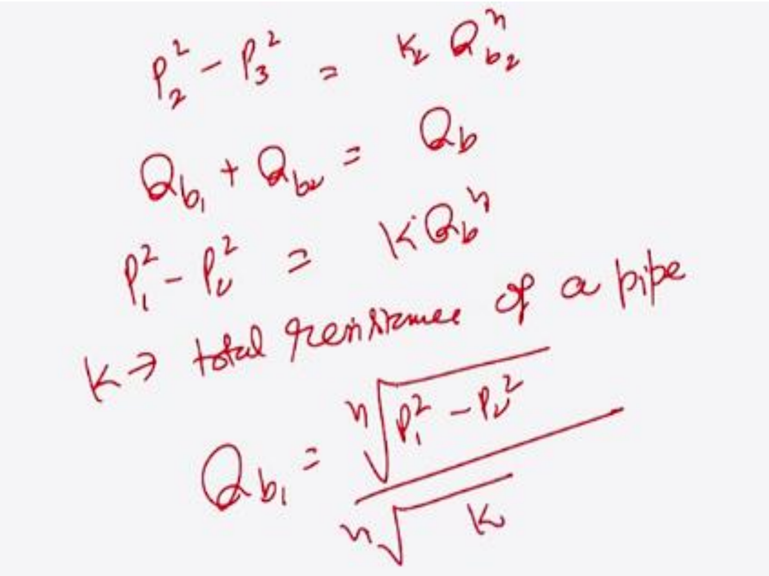
The governing equation for pressure drops for each segment will be represent as;

$$P_1^2 - P_2^2 = K_1 Q_{b1}^n$$



Now, P 2 square – P 3 square = K 2 Q b 2 to the power n where Q b 1 + Q b 2 = Q b and generally P 1 squared – P 2 square = K Q b to the power n. Now, K is the total resistance of a pipe substituted for loop. So, if we rearrange the above equation, we get Q b 1 = P 1 square minus – P 2 square upon K 1.

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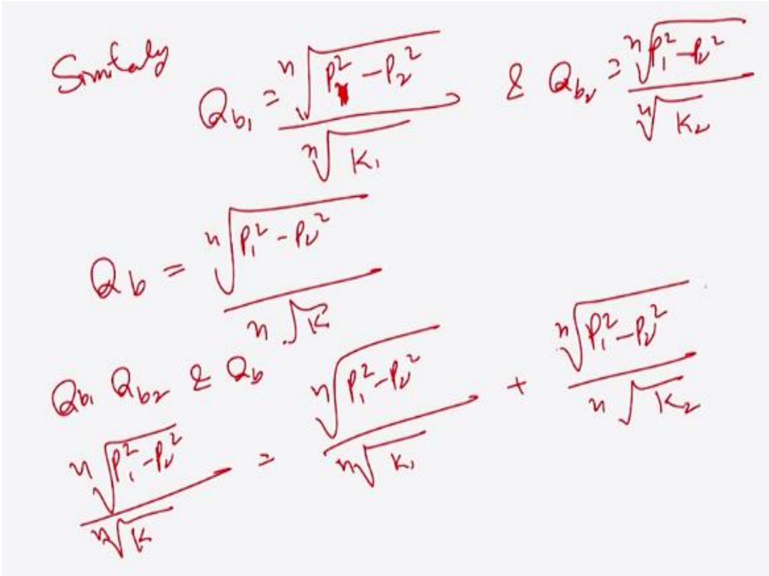
$$P_2^2 - P_3^2 = K_2 Q_{b2}^n$$

Where, $Q_{b1} + Q_{b2} = Q_b$

Generally, $P_1^2 - P_2^2 = K Q_b^n$

Where K is the total resistance of a pipe substituted for loop, on rearranging the above equations we have;

$$Q_{b1} = \frac{\sqrt[n]{P_1^2 - P_2^2}}{\sqrt[n]{K_1}}$$



Now, similarly Q b 1 is equal to or Q b 1 is represented as minus P 2 square upon nth root of K 1 and Q b 2 = nth root of P 1 square – P 2 square upon nth root of K 2 and the general equation can be represented as Q b = n root of P 1 square – P 2 square upon nth root of K. Now, if we substitute the value of Q b 1, Q b 2, and Q b we have nth root of P 1 square – P 2 square upon nth root of K that is equal to nth root of P 1 square – P 2 square upon nth root of K 1 + P nth root of P 1 square – P 2 square upon nth root of K 2.

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Similarly,

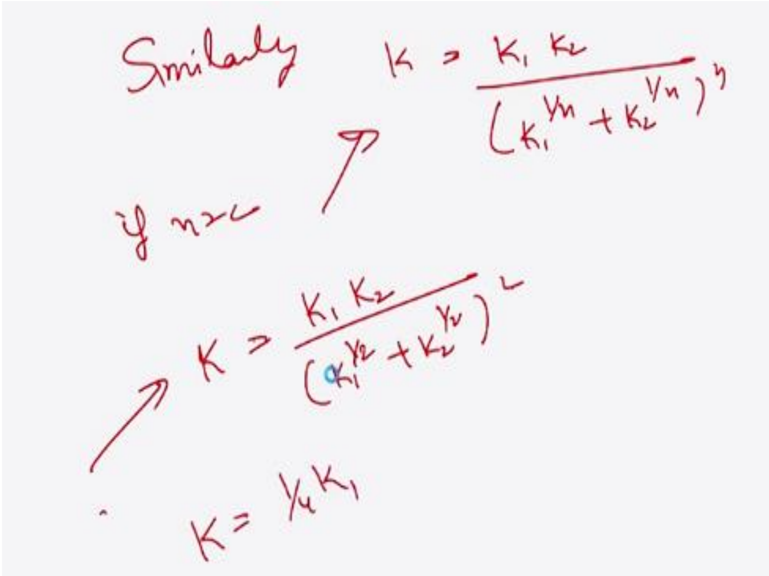
$$Q_{b1} = \frac{\sqrt[n]{P_1^2 - P_2^2}}{\sqrt[n]{K_1}} \quad \text{and} \quad Q_{b2} = \frac{\sqrt[n]{P_1^2 - P_2^2}}{\sqrt[n]{K_2}}$$

General equation,

$$Q_b = \frac{\sqrt[n]{P_1^2 - P_2^2}}{\sqrt[n]{K}}$$

Now substitute values of Q_{b1}, Q_{b2} and Q_b, we have;

$$\frac{\sqrt[n]{P_1^2 - P_2^2}}{\sqrt[n]{K}} = \frac{\sqrt[n]{P_1^2 - P_2^2}}{\sqrt[n]{K_1}} + \frac{\sqrt[n]{P_1^2 - P_2^2}}{\sqrt[n]{K_2}}$$



Similarly, K = K 1 K 2 upon K 1 to the power 1 over n + K 2 to the power 1 over n n. Now if n = 2 this above equation given the total resistance of two pipelines in parallel and which can be given as K = K 1 K 2 upon K 1 to the power half + K 2 to the power half square, where K is the total resistance of two pipeline looped together. Now, if two pipelines have equal diameter, then K = 1 upon 4 K 1.

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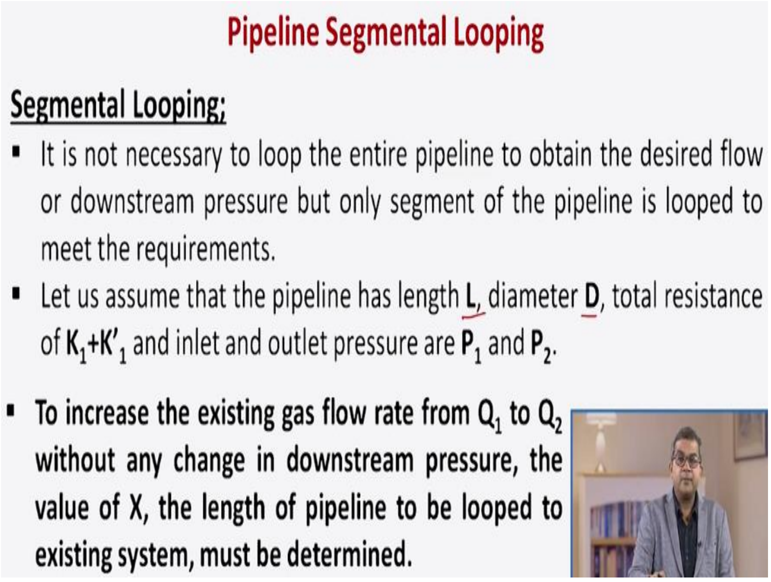
Similarly,

$$\boldsymbol{K = \frac{K_1 . K_2}{(K_1^{1/n} + K_2^{1/n})^n}}$$

If n=2, the above equation giving total resistance of two pipelines in parallel is given as;

$$\boldsymbol{K = \frac{K_1 . K_2}{(K_1^{1/2} + K_2^{1/2})^2}}$$

Where, K is the total resistance of the two-pipeline looped together. If two pipelines have equal diameters, then K= ¼ K_1.



Now, let us talk about the pipeline segmental looping. Now, segmental looping it is not necessary to loop the entire pipeline to obtain the desired flow or downstream pressure, but only segment of the pipeline is looped to meet the requirement. Now, let us assume that the pipeline has the length L and diameter D and the total resistance is K 1 + K 1 dash and the inlet and outlet pressures are P 1 and P 2. Now to increase the existing gas flow rate from Q 1 to Q 2 without any change in the downstream pressure, the value of X that is the length of the pipeline to be looped to existing system must be determined.

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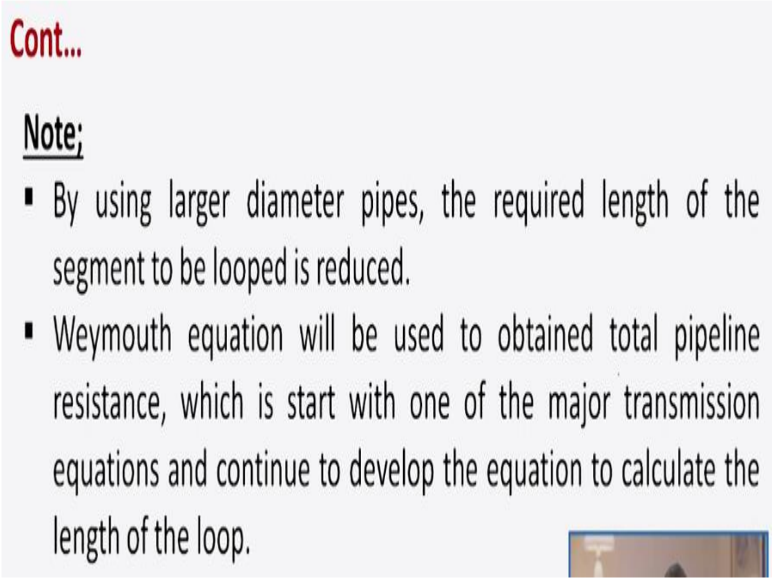

Now, by using the larger diameter pipes, the required length of the segment to be looped is usually reduced. Now, Weymouth equation can be used to obtain total pipeline resistance, which is start with one of the major transmission equations and continue to develop the equation to calculate the length of the loop.

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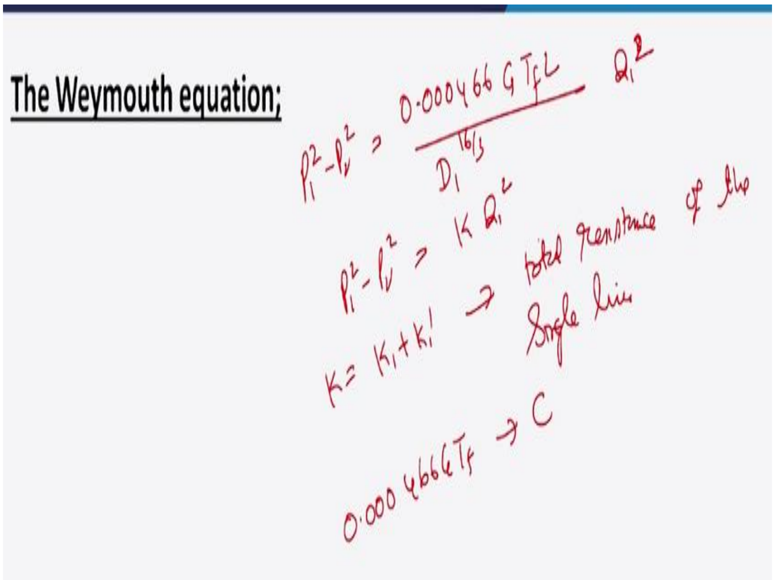

So, again coming back to Weymouth equation, that is P 1 square – P 2 square and that is equal to 0.000466 G T f upon L over D 16 by 3 Q 1 squared or P 1 square – P 2 square = K Q 1 square where K = K 1 + K 1 dash, this is the total resistance of the single line. For the total resistance of Weymouth equation, the value of 0.000466 G T f is constant and named as C.

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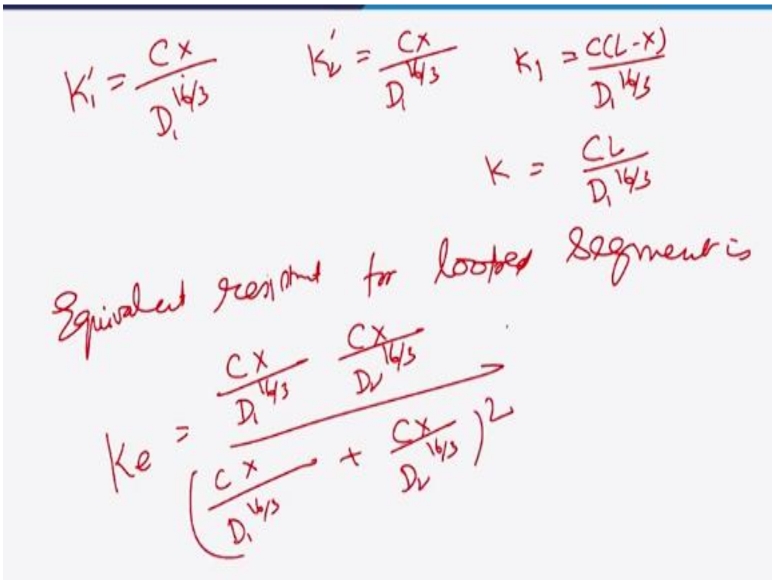
The Weymouth equation;

$$\boldsymbol{P_1^2 - P_2^2 = \frac{0.000466G.T_f.L}{D_1^{16/3}} Q_1^2}$$

Or $$\boldsymbol{P_1^2 - P_2^2 = K.Q_1^2}$$



Now, K 1 = C x D 1 16 by 3, K 2 dash = C x upon D 1 16 by 3, K 1 = C L – x upon D 1 16 by 3 and K = C L upon D 1 16 by 3. The equivalent resistance for looped segment is K e = C x upon D 1 16 by 3, C x = D 2 16 by 3 upon C x D 1 16 by 3 + C x upon D 2 16 by 3 whole square.

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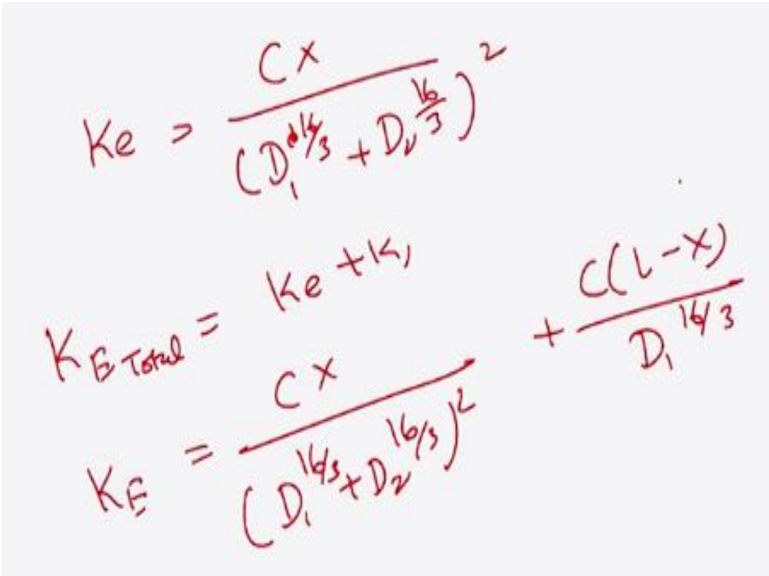
Where, K= K_1+K'_1 is the total resistance of the single line.

For total resistance of Weymouth equation, the value of $0.000466GT_f$ is constant and named as C.

$$K'_1 = \frac{C.X}{D_1^{16/3}}, \quad K'_2 = \frac{C.X}{D_1^{16/3}}, \quad K_1 = \frac{C.(L-X)}{D_1^{16/3}}, \quad \text{and} \quad K = \frac{C.L}{D_1^{16/3}},$$

The equivalent resistant for the looped segment is;

$$K_e = \frac{\frac{C.X}{D_1^{16/3}} \cdot \frac{C.X}{D_2^{16/3}}}{\left(\frac{C.X}{D_1^{\frac{16}{3}}} + \frac{C.X}{D_2^{\frac{16}{3}}}\right)^2}$$



Now, if you simplify then then K e = C x D 1 16 by 3 D 2 16 by 3 whole square. Now K e total = K e + K 1. So, if we rearrange K e, then K e becomes C x upon D 1 16 by 3 + D 2 16 by 3 square + C L – x upon D 1 16 by 3.

(Refer Slide Time: 29:46)

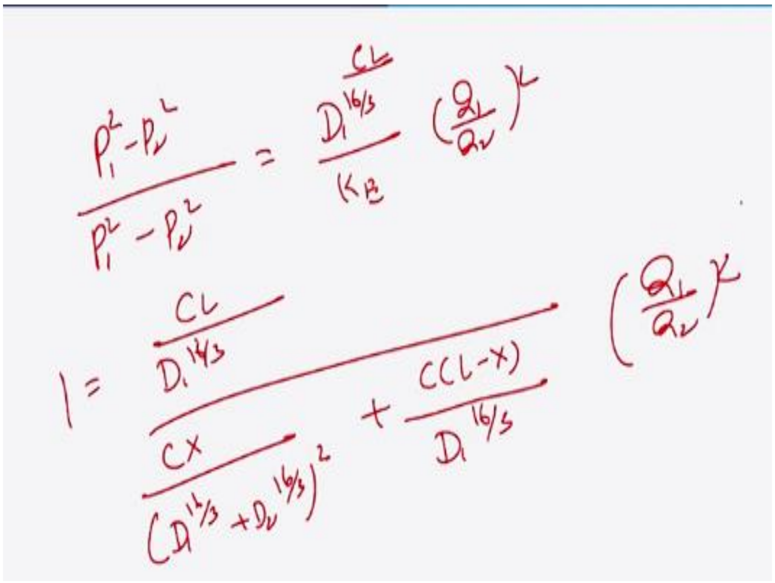
On simplification K_e, we have;

$$K_e = \frac{C.X}{\left(D_1^{\frac{16}{3}} + D_2^{\frac{16}{3}}\right)^2}$$

$K_{E\ Total} = K_e + K_1$ (i.e., Pipes in series)

Then, on rearranging for K_E total we have;

$$K_E = \frac{C.X}{\left(D_1^{\frac{16}{3}} + D_2^{\frac{16}{3}}\right)^2} + \frac{C.(L-X)}{D_1^{16/3}}$$



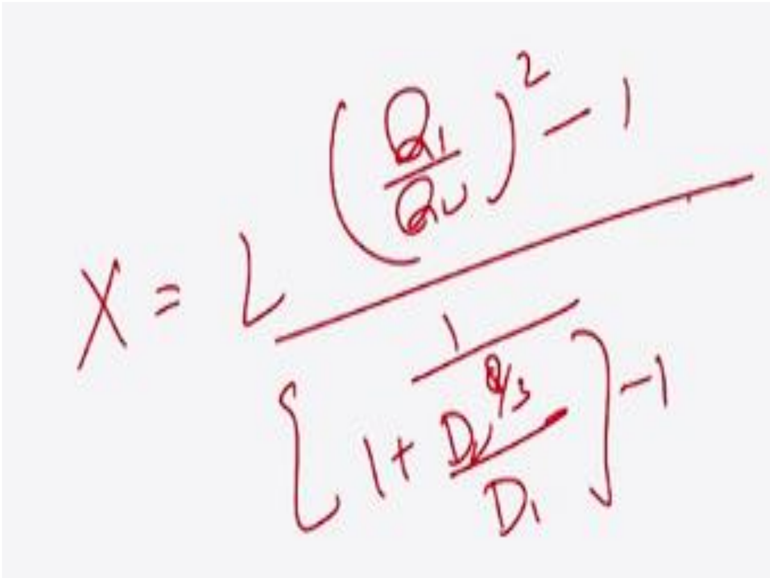
Now, upon dividing the flow equation for existing pipeline after segmental looping we have P 1 squared – P 2 square upon P 1 square – P 2 square = D 1 C L D 1 to the power 16 by 3 upon K e Q 1 upon Q 2 square or 1 = C L D 1 to the power 16 by 3 whole upon C x upon D 1 16 by 3 + D 2 16 by 3 whole square + C L –x upon D 1 16 by 3 Q 1 upon Q 2 whole square.

(Refer Slide Time: 30:38)

On dividing the flow equations for existing pipeline and after segmental looping, we have;

$$\frac{P_1^2 - P_2^2}{P_1^2 - P_2^2} = \frac{\frac{CL}{D_1^{\frac{16}{3}}}}{K_E} \cdot \left(\frac{Q_1}{Q_2}\right)^2$$

Or, $$1 = \frac{\frac{CL}{D_1^{\frac{16}{3}}}}{\frac{C.X}{\left(D_1^{\frac{16}{3}} + D_2^{\frac{16}{3}}\right)^2} + \frac{C.(L-X)}{D_1^{16/3}}} \cdot \left(\frac{Q_1}{Q_2}\right)^2$$



So, the equation becomes X = L Q 1 upon Q 2 square – 1 upon 1 upon 1 + D 2 8 by 3 upon D 1 – 1.

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The equation will become;

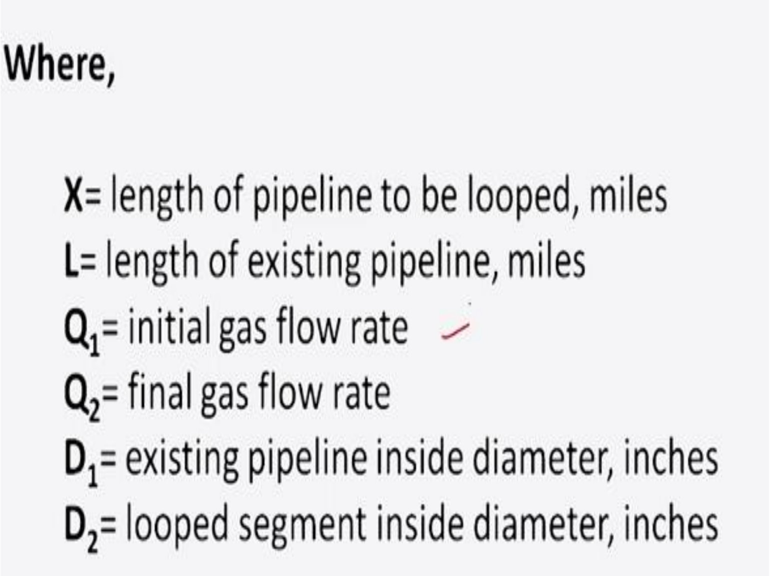
$$X = L.\frac{\left(\frac{Q_1}{Q_2}\right)^2 - 1}{\left[\frac{1}{1+\frac{D_2{}^{\frac{8}{3}}}{D_1}}\right]^2 - 1}.$$

Where,

X= length of pipeline to be looped, miles

L= length of existing pipeline, miles

Q_1= initial gas flow rate



Now where X that is a length of pipeline to be looped that may be in miles, L is the length of existing pipeline in miles. Q 1 that is the initial gas flow rate, Q 2 is the final gas flow rate if you see and D 1 is the existing pipeline inside diameter in inches and D 2 is the looped segment inside the diameter which is represented in inch.

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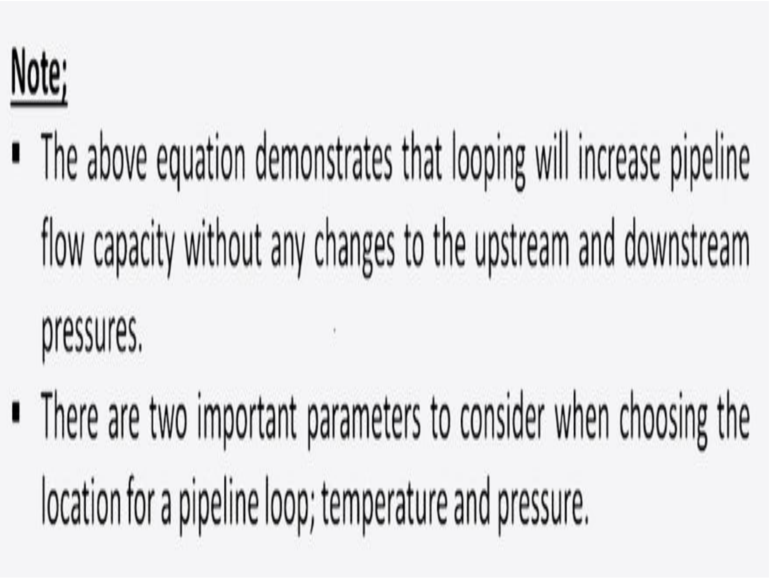

Now, this equation demonstrates that the looping will increase pipeline flow capacity without any changes to the upstream and downstream pressures. Now, there are two important parameters which we need to consider when choosing the location for a pipeline loop that is temperature and pressure. So, a class in this particular segment we discuss the various pipeline configuration series and a parallel, we devise the equations with respect to the other parameters in question.

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References

- M. Mohitpour, H. Golshan, A. Murray, PIPELINE DESIGN & CONSTRUCTION: A Practical Approach; Third Edition, American Society of Mechanical Engineers., (2007), ISBN 0-7918-0257-4.

For reference, we have enlisted a reference for your convenience. Thank you very much.