Fluid Mechanics & its Applications
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Lecture 20A
Losses in Pipe-Fittings

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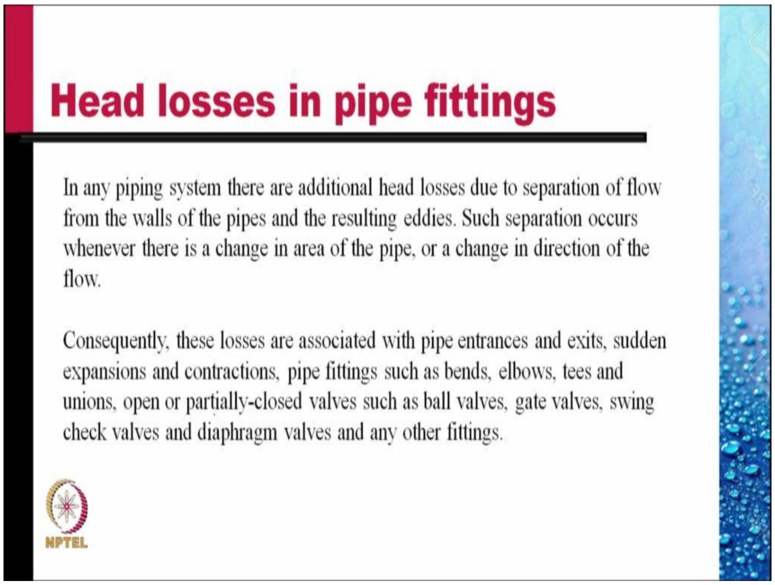

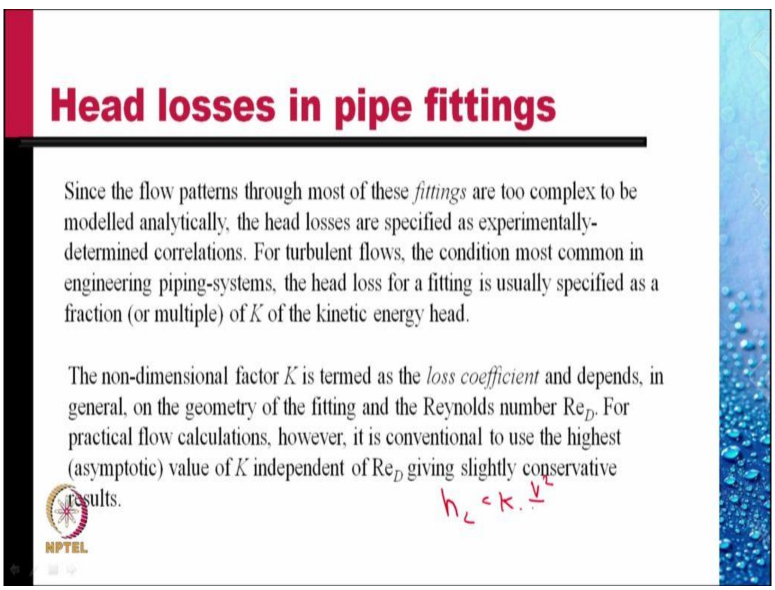

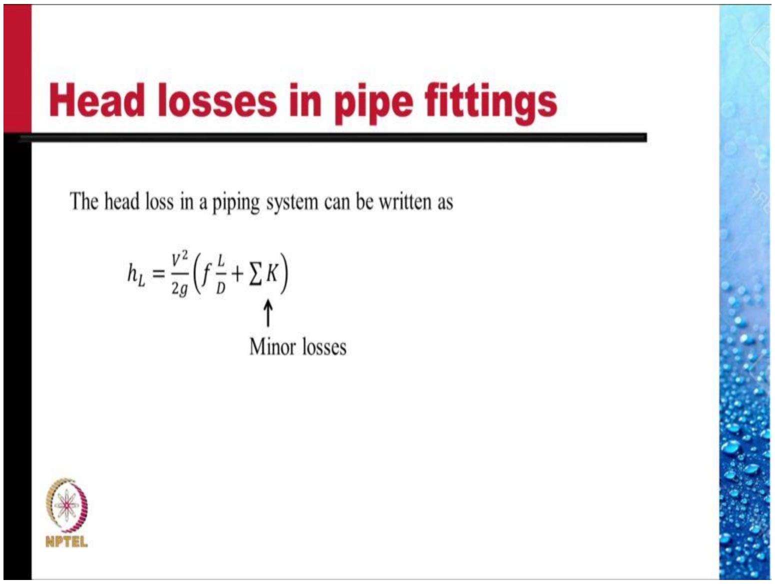

In any piping system, there are additional head losses due to separation of flow from the walls of the pipe and resulting eddies. Such separation occurs whenever there is a change in area of the pipe, or a change in direction of the flow, that is, at pipe fittings. Consequently, these losses are associated with pipe entrances and exits, sudden expansion and contraction, in pipe fittings such as bends, elbows, tees and unions; open or partially closed valves such as ball valves, gate valves, swing check valves, and diaphragm valves, and in any other fittings.

Since the flow patterns through most of these fittings are too complex to be modeled analytically, the head losses are specified as experimentally-determined correlations. For turbulent flows, that is the condition in most engineering piping-systems, the head loss for a fitting is usually specified as a fraction or multiple K of the kinetic energy head. The non-dimensional factor K is termed as the loss coefficient, and depends, in general, on the geometry of the fitting, and the Reynolds number. For practical flow calculations, however, it is conventional to use the highest asymptotic value of K, independent of the Reynolds number, giving us slightly conservative results.

Therefore, the head loss through any fitting can be expressed as h_L hl is equal to K times the velocity head. So, the head loss is $h_L = \frac{V^2}{2g}\left(f\frac{L}{D} + \sum K\right)$. $\sum K$ is called the minor losses, because in most piping system $f\frac{L}{D}$ is much larger than $\sum K$.

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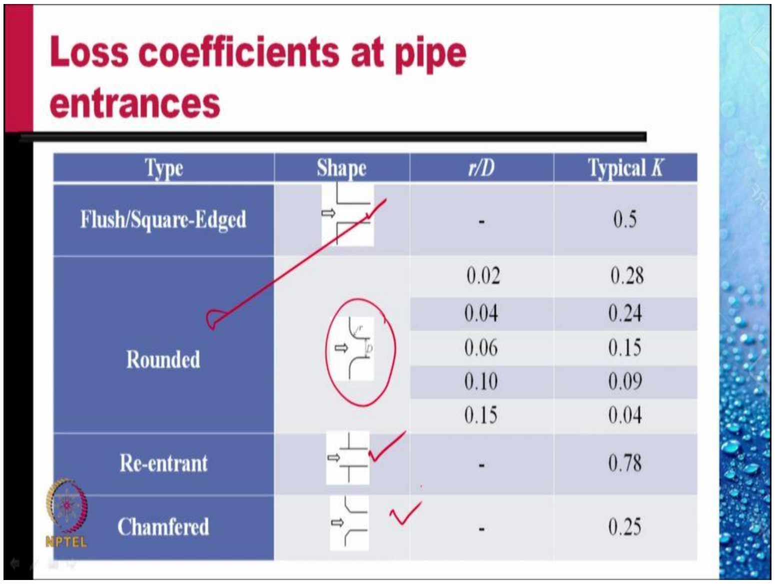

Type	Shape	r/D	Typical K
Flush/Square-Edged		-	0.5
Rounded		0.02	0.28
		0.04	0.24
		0.06	0.15
		0.10	0.09
		0.15	0.04
Re-entrant		-	0.78
Chamfered		-	0.25

We give here the head loss coefficients K for the various pipe fittings.

In this first slide, we talk of the pipe entrances. If I have a flush or a square-edged entrance as shown here, the typical value of K is 0.5. When the entrance is rounded, the value of K depends upon r/D, the radius of the rounding and the diameter of the pipe, and for r/D varying from 0.02 to 0.15, the values of K are 0.28 to 0.04, 0.28 when the radius of the round is least, and 0.04, a low value, when the radius is large. For a re-entrant pipe, one shown here, the value of K is quite large 0.78. For chamfered entrance, the value of K is 0.25.

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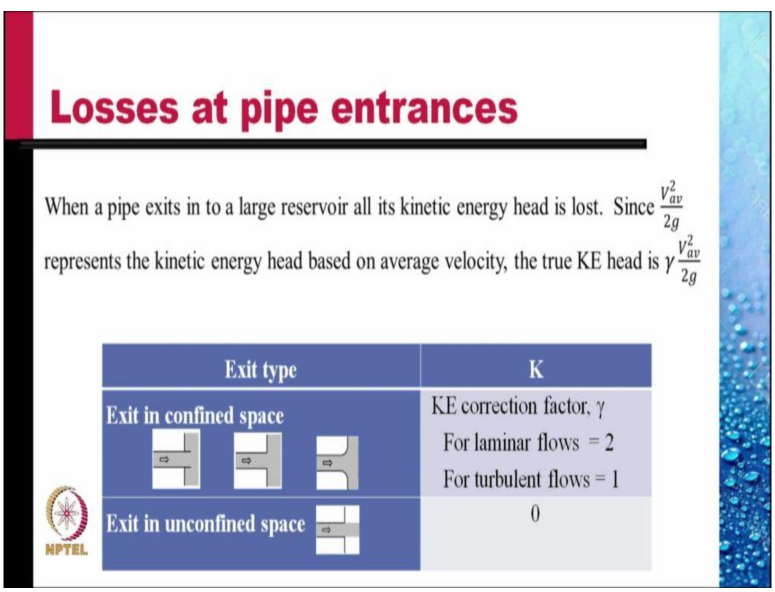

Exit type	K
Exit in confined space	KE correction factor, γ For laminar flows = 2 For turbulent flows = 1
Exit in unconfined space	0

When a pipe exits in to a large reservoir, all its kinetic energy head is lost. Since, $\frac{V^2}{2g}$ represent the kinetic energy head based on the average velocity, the true kinetic energy head is $\gamma\frac{V^2}{2g}$, where γ is the kinetics energy correction factor. So, when the exit is in a confined space, that is, the pipe is exiting into a tank, then all of the kinetic energy is lost. And we have kinetic energy factor equal to the value of K. For laminar flows, the kinetic energy correction factor is 2. For turbulent flow, the kinetic energy correction factor is 1. And when the flow exits into unconfined space, that is, it comes out as a jet, no energy is lost, and so, the value of K is 0.

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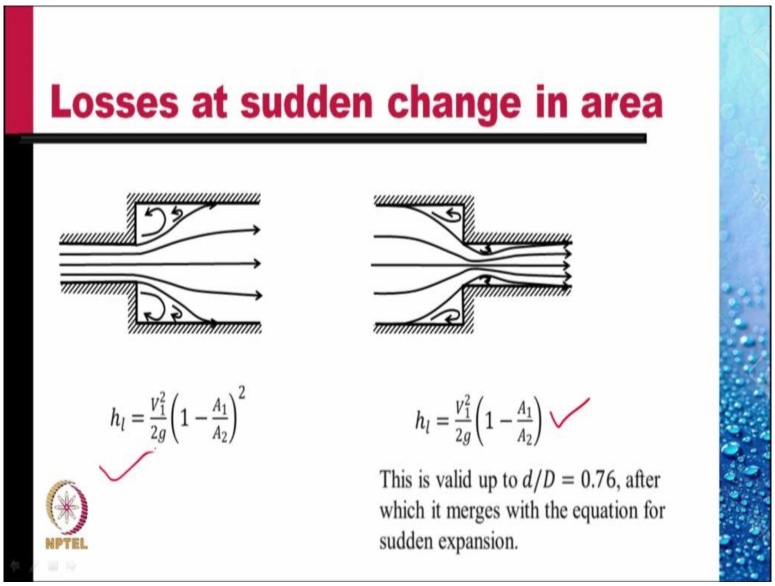

Losses at a sudden change in area. At a sudden expansion, the head loss is given by $h_l = \frac{V_1^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$. This had been obtained in an earlier lecture. The losses at a sudden decrease in area, sudden contraction, is given by this formula. This is valid up to d/D is equal to 0.76, lowercase d is the value of the smaller pipe, D is the diameter of the larger pipe from which the flow is coming. When d/D is larger than 0.76, the result is like this.

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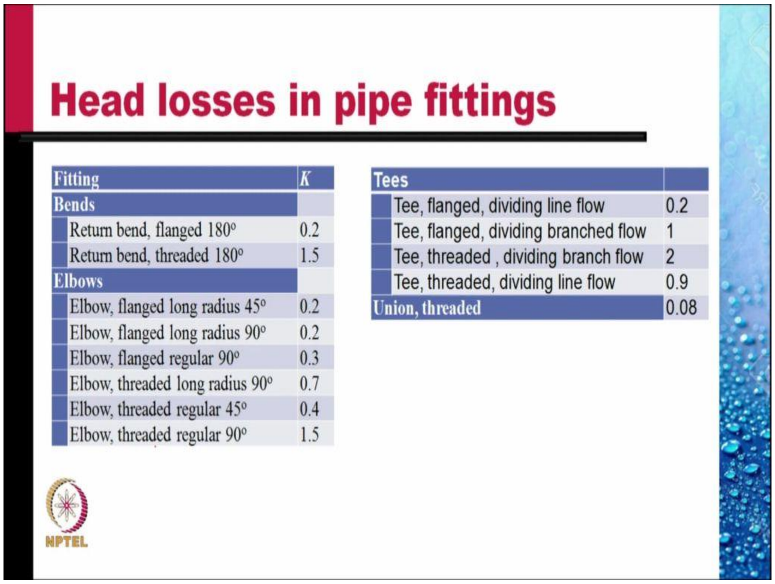

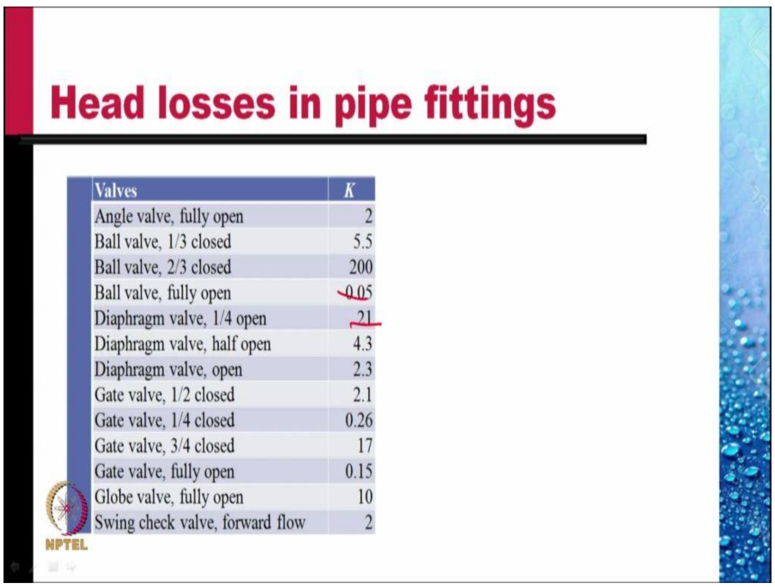

This table gives you the head losses for the various kinds of pipe fittings: bends, elbows, tees, unions. These are typical values. A piping engineer refers to the data supplied by the manufacturer of the fittings to determine what the actual value of K would be. Head losses in the valves vary widely depending upon how much closure is there. For example, a ball valve fully open results in a K value of 0.05, 0.05. But, while it is two-thirds closed, the value is as high as 200.

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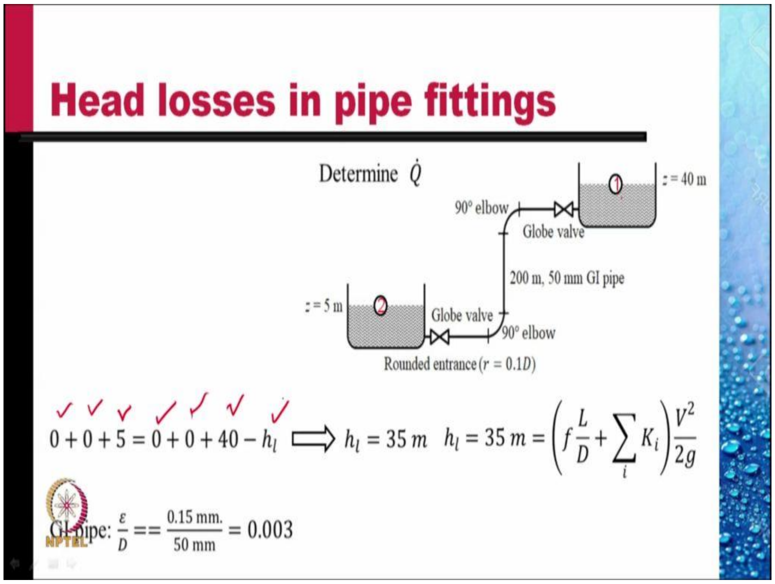

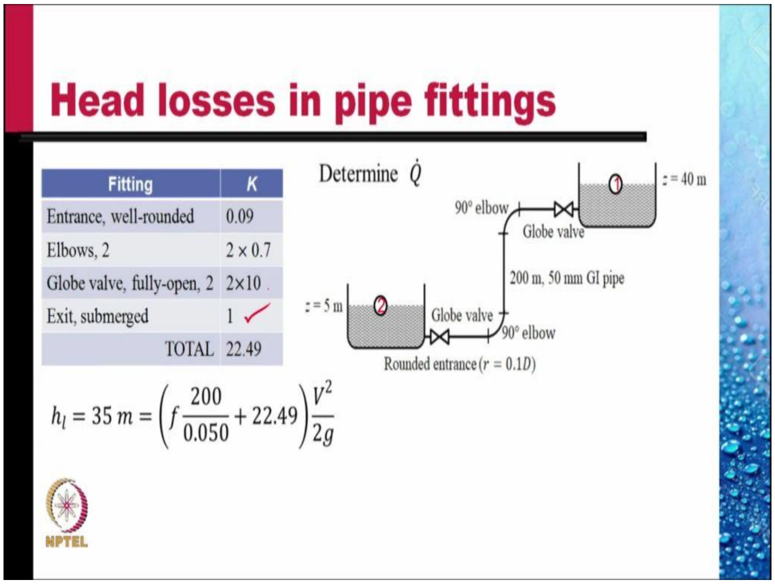

Let us do an example. The diagram shows a piping system in which a 200-m, 50-mm galvanized iron pipe is connecting two reservoirs. One reservoir at an altitude of 40 m, and the other reservoir in which the level is at 5 m altitude. There are two globe valves, two 90-degree elbows into the system. There is an entrance, the water is flowing from the higher reservoir into the lower reservoir, and there is an exit.

So, there will be two kinds of head losses, one because of friction in the pipe, and the other the minor losses because of pipe fittings. First, we apply the Bernoulli equation between point 1 and point 2 shown. At the exit, the total head consists of the pressure head, the velocity head, and the altitude head. This is at the exit.

And this is equal to the total head at the entrance minus the head loss. Total head at the entrance: the velocity at 0 at 1, 0 is the pressure at 1 which is open to atmosphere. Altitude is 40 m minus h_l. So, this gives you h_l is equal to 35 m. We are losing 35 m head in the flow of water. The head loss is given by this formula.

For the GI pipe, ε/D can be determined. ε is 0.15 mm for galvanized iron pipe. The diameter of the pipe is 50 mm, so ε/D value is 0.003. We determine the $\sum K$ for the minor losses. We have a well-rounded entrance that is given to us, so the value of K is 0.09 from the table. There are two large radius elbows. Each elbow has a coefficient of 0.7, so, for two elbows it will be 2×0.7. We have two fully-open globe valves, each with K is equal to 10, and a submerged exit. And we have assumed the flow to be turbulent, the value of K is 1. $\sum K$ then would be 22.49. And from the head loss equation, we get this. We need the value of f to determine $\frac{V^2}{2g}$. We can follow the same process that we followed earlier.

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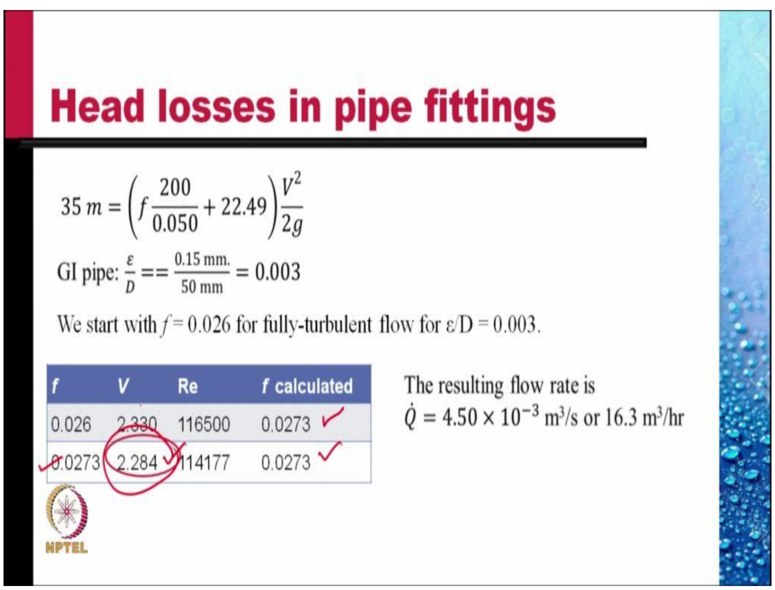

And by iteration, we can determine the values. Since, D is given, an ε/D can be calculated. We look up the value of f for the fully-developed turbulent flow in pipes with ε/D, the relative roughness of 0.003, and we obtain f as 0.026. And then, we do iterations. From the first value we get a velocity of 2.330, and the *f* can be calculated from either the Moody chart or the Colebrook calculator, and the value comes out to be 0.0273.

We use this as a starting value in the next round. The velocity now comes out to 2.284. The Reynolds number changes slightly, but the value of *f* is unchanged. And since the value of *f* has not changed, our iterations are over, and the results have converged. The value of velocity through pipe is 2.284 meters per second. Of course, the number of significant figures we have specified are much more than what is valid. With this velocity, the volume flow rate is 16.3 m^3/hr.