Types of Flow

SPEAKER Rick Huizinga : This is Lesson 5 and we're going to be talking about Velocity Profiles, and I'd like to start off with addressing a few of the key concepts in this lesson partially because I know it's helpful to be able to see where we're going to go. This is basically a road map that will take you to the end of the lecture and will give you an idea of where we're going to be going with this lecture. In this lecture we're going to be talking about the characterization of flow types, and there are typically two types flow, laminar flow and turbulent flow.

And then as we talk about the types of flow, there is a velocity distribution equation and a way to compute unit discharge and mean velocity for laminar flow as well as for turbulent flow. These are the velocity distribution equation for laminar flow, the unit discharge equation, the mean velocity equation as well as a depiction of the velocity profile for laminar flow. In turbulent flow there's a different equation for the velocity distribution and it's called the Prantdl-von Karman Universal Velocity Distribution Law, and then there is also the unit discharge equation. The term "E" there is the logarithmical base, and we'll talk about that a little bit more later in the lecture and the, of course, the mean velocity.

A gentleman by the name of Osborne Reynolds in 1883 characterized flow or he demonstrated that flow typically fell into two categories, laminar and turbulent. And for laminar flow, he found that it typically occurred at low velocities and when he would inject a stream of dye into water, the dye would flow basically in a straight line. This implied to him that the particles all move parallel to one another, and the fluid appeared to move by the sliding of layers on top of one another. These particles move in a very definite and observable streamline, and so laminar flow is also typically called "streamlined flow" or "viscous flow."

And the shear stress in the fluid can be defined by the term that we saw in Lesson 1, tau is equal to “mu” times the quantity DV over DY where “mu” is the dynamic viscosity and DV, DY is the variation of velocity with respect to depth. For turbulent flow, Osborne Reynolds found that this occurs at higher velocities and that if you inject a stream of dye into water, the dye disburses very

rapidly, which means that the particles of water are moving in a much more erratic pattern. Rather than being parallel to one another, they flow erratically. This results in very irregular flow patterns and these patterns are typically not very easy to observe in actual channels.

Now, for predicting the type of flow, he developed a term called "The Reynolds Number" and we were introduced to that concept in Lesson 3. The Reynolds Number, and it's depicted several ways, sometimes as a capital "R", sometimes with a sub "e" and sometimes not. But it is the ratio of inertial to viscous forces, and you can see there in the slide that it's equal to the velocity times “rho”, which is the density of the fluid times the characteristic length L over “mu” the dynamic viscosity, or it can also be written in terms of the kinematic viscosity as V times the characteristic length over the kinematic viscosity.

Now "V" again is the velocity of flow, “rho” is the density of the fluid, “mu” is the dynamic viscosity or this Greek Nu which is the kinematic viscosity, and L is this characteristic length. And in pipe flow, it's the pipe diameter but in open channel flow, it's typically the depth of the flow. In pipe flow generally speaking, flow is laminar when the Reynolds Number is less than 2,000, and it's turbulent when the Reynolds Number is greater than 4,000. Obviously, there's a transition range in between these two values, and this critical Reynolds Number, that transition point between laminar and turbulent flow, is very much dependent upon the boundary of the pipe.

If the pipe is more rough, it will tend to be towards one side of that range or the other. Now, in open channel flow, this critical transition Reynolds Number is closer to 500, which is quite a bit lower than it is in pipe flow, and it must be determined experimentally. Now, we're going to take a break and look at flume demonstration of what laminar and turbulent flow looks like.