Hello, and welcome to Engineering Earth. In this video we are going to review the concepts of total head and hydraulic head, as well as their application to construct hydraulic and energy grade lines across flow systems.

So we'll recall that the mechanical energy of a flow system can be expressed in units of total head, which we give the variable capital H. And total head is the sum of our pressure head, our kinetic head, and our elevation head. So of course I'm correcting for any non-uniformity in my velocity distribution by including my alpha parameter, my kinetic correction factor right here to modify my velocity head. If I consider just a subset of this energy, I can define the hydraulic head. And this is given by the variable lowercase h. And this is just, like I said, a subset of total head, it's the combination of my pressure and elevation head. So you can see that the difference between total head and hydraulic head is nothing more than just the kinetic head, V squared over 2g. So at any given point in my flow system I can define um my total head, H, as a height above my datum. So let's say that I've got a datum right here, this is where my z is equal to zero, and then I can express my total head as the sum of elevation. So let's say at this given point in the flow system, this is my elevation, z. Here's my pressure head oops sorry, P over rho g and then my velocity head. And so the sum of all three, this is going to be my total head H. And my sum of the pressure head and elevation head right here, this is going to be the value of hydraulic head. And you can see that the difference between them is nothing more than just the velocity head.

If I graph the total head along a system, so instead of just estimating at a point, if I estimate it at multiple points and then put those points together, then I'm going to construct what's known as an energy grade line. So this is just telling us about how the total mechanical energy of flow is varying as we move along a flow system. And then similarly if I do the same thing for hydraulic head if I graph hydraulic head along the system, then I'm going to make my hydraulic grade line. So let's consider a relatively simple example of a system where we've got a fluid flowing through a long horizontal pipeline with a constant diameter, D. So here is my pipeline, it's got a constant diameter, D, along its length. And then let's say that here is my horizontal datum down here where z is equal to zero. And I'm going to consider two different points um along my my pipeline, one here and two right here. So at my point one I'm going to estimate my hydraulic energy, I'm sorry my total head as the sum of my elevation head, so here's my elevation at z1 and then I've got my pressure head here and my velocity head here. And if I add all of these together I'm going to get my total head, H1. Now if I think about doing the same kind of estimate at point 2, I know that my H2 has to be a little bit lower than H1. Why is this? Well I know that as my fluid is flowing along the pipeline just a little bit of that energy is being lost to friction as it flows along. And so my total energy grade line between um one and two is going to have this downward slope. And so if I compare you know for instance to the horizontal. Right, so this was my kind of initial energy. If I look at the difference between H1 and H2, what is the value this is going to be? The amount of energy that was lost due to friction. So now let's think about how that is going to affect each of my three components of, of my total head. z2 is still at the same elevation as z1 right, it's a horizontal pipeline. So z2 and z1 are the same. So clearly there can't be any changes that have happened within my elevation head. So let's look at velocity. The pipeline diameter down here at two is the same as it was at one, my flow is steady through the pipeline. The cross-sectional area isn't changing so, therefore, my velocity can't change and that means that my velocity head also cannot change. So my V2 over 2g is going to be the same as V1 over 2G because my velocity hasn't changed. So what that means is that the change has to have happened within my pressure head term. So my P2 over rho g is just slightly smaller than P1 over rho g, and the difference between the two is the head loss due to friction. And so if I want to construct my hydraulic grade line, you can see my energy grade line is already there between capital H1 and capital H2, but my hydraulic grade line is going to be between these two points lowercase h1 and 2.

So let's think about a more complicated example same kind of thing but just a little bit more going on within our flow system. So this time I'm going to still construct my energy grade line in red and my hydraulic grade line in blue. And this time my flow system, it's still a pipeline, still an internal flow but my pipeline goes from a big diameter and then contracts into a small diameter, and then the flow goes through a pump. It comes back out at the same pipe size and then expands again to a larger pipe size diameter. And so I'm going to consider kind of a number of sections along this pipe, like this. And construct my total head and hydraulic head as we're moving along that energy grade line. So at point 1, at some distance above my datum let's say that my total energy looks like this, this is my H1. If I think about what's going to happen between point 1 and 2, there's going to be just a small amount of decrease in the total energy, of course because of the, the loss in in energy due to friction. So I've got like this gradual downward sloping between between one and two and again if I compare this to the horizontal, that distance is going to have the value of energy that's been lost to friction as the flow has gone between points one and two. So then, at my next point H3 my flow is going through a pump and you know the the whole purpose of a pump is to raise the energy of the flow, so I know that total head at point 3 is going to go up sharply from 2. And then after the the flow and uh exits the pump into four and travels through the rest of the pipeline, through five. Again, I'm going to see that sort of gradual depreciation of energy that's happening through the pipeline, as energy is lost through friction. And this should be a pretty gradual downward decline. Let me modify where my H5 should be, right about there/ Okay so now I've got a depiction of my energy grade line, let's think about my where my hydraulic grade line should be. So this is a horizontal system so there's not going to be any change in elevation head. There definitely could be a change in pressure head, especially right here where this pump is. So the main way that the pump is going to increase the energy of the flow is by raising the pressure of the flow. now the other thing that's happening is that my velocity head is going to be varying along this pipeline as the pipeline diameter changes, right. So let's just say that my velocity head at point 1 looks like this. And let's think about how that might change as we go from point 1 to 2. At point 1 we have a big cross-sectional area in our pipeline. At 2 we have a smaller cross-sectional area. So, since the flow can't change from 1 to 2, that change in cross-sectional area is going to increase the flow speed, which will increase the velocity head. So I'll have a much bigger velocity head at point 2. And then that velocity head isn't necessarily going to change because of the pump. And then at H4 my cross-sectional area of the pipe still hasn't changed very much so at points 2, 3, and 4 my velocity head is going to be somewhat similar, not so much of a change. And then when I get to point 5, now I'm back into a larger pipe size and so now my velocity head's going to go back down again. And so if I want to construct my hydraulic grade line, I now have all the points that I need to do that. So I've got a decrease right away in my hydraulic grade line that has to do with the increase in velocity head as my pipeline contracts, big increase in my hydraulic grade line corresponding to the pressure increase given by this pump, and then kind of that long slow progression in my hydraulic grade line, reflecting the the energy loss due to friction plus the decrease in velocity head as my pipeline goes from small diameter back to a large diameter.

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Great job reaching the end of this video and now you can reward yourself with a moment of zen. I study fluid mechanics because I love water and healthy aquatic ecosystems. Whatever your passion is, I hope that it motivates you to continue your study of fluid mechanics.