Oil Hydraulics and Pneumatics

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Basic Laws of Oil Hydraulics and Pneumatics
Lecture – 08
Part 2: Pressure Intensifier, Numericals, Air-to-Hydraulic Booster and Bernoulli equation

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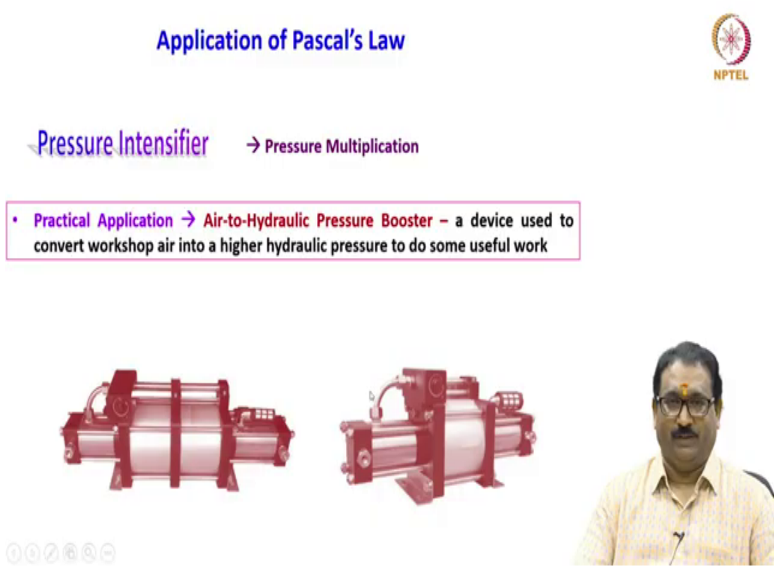

My name is Somashekhar course faculty for this course, ok. Now, we will move on to the one more applications of Pascal's law pressure intensifier, these are the devices used for pressure multiplication. Practical application involves air to hydraulic pressure booster; these are the device used to convert the workshop air, which is generally six bar into a higher hydraulic pressure to do some useful work.

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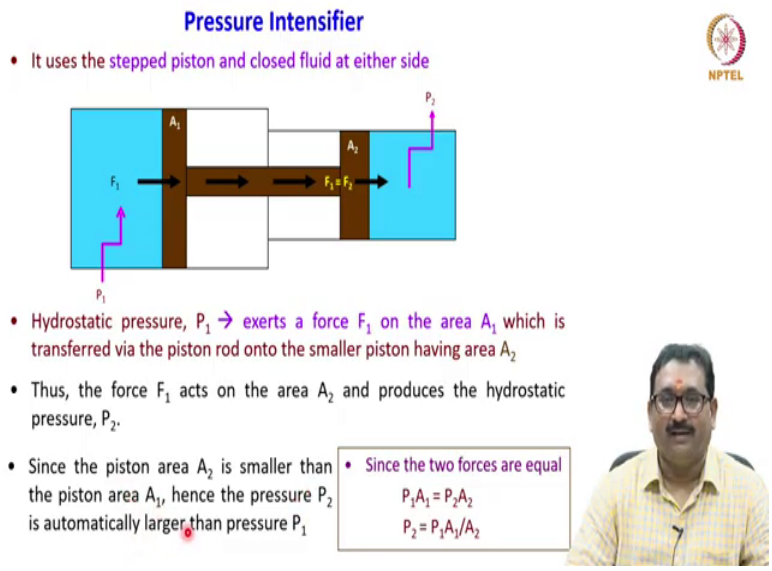

These are the devices generally used in industry for the pressure multiplication purpose. Pressure intensifier how it will work see here; it uses the stepped piston and a closed fluid at either side of the stepped piston; very simple it is friends, pressure intensifier is fitted with the stepped piston on either side a closed contained fluid.

Let us we will see here, this is very simple; you will see here. it is a stepped piston here, correct friends, stepped piston and the two side of the stepped piston is a fluid contained here. Now, we will see here I marked P 1 is where I am adding the pressure to the here; it will generate the force, the same force acting at the other side. According to the Pascal's law, you will see the hydrostatic pressure P 1 exerts a force F 1 on the area A 1, which is transferred via the piston rod onto the smaller piston having area A 2.

Thus, the force F 1 acts on the area A 2 and produces the hydrostatic pressure P 2. Since the piston area A 2 is smaller than the piston area A 1; hence the pressure P 2 is automatically larger than the pressure P 1. Because as we know the pressure intensifier F 1 equal to F 2, then P 1 A 1 equal to P 2 A 2; then P 2 is P 1 by P 1 A 1 by A 2, correct friends.

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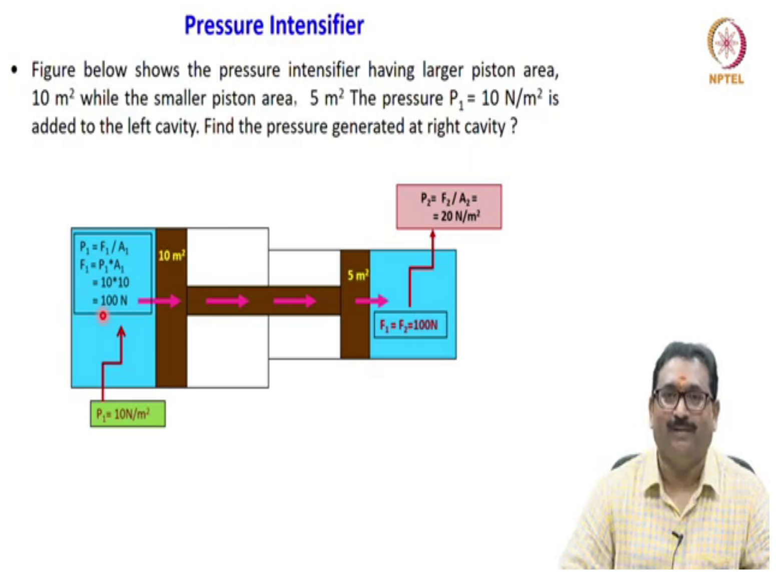

I will show you a simple numerical, how the pressure is multiplied in the pressure intensifier. You will see here friends, again I have drawn the same figure here; figures below shows the pressure intensifier having a larger piston area 10 meter square assumed to be and a smaller piston area 5 meter square 2 is to 1, correct it is a 2 times, it is a 1 time assumed to be.

The pressure P 1 100 Newton meter square is added to the left cavity. Find what is a force generated here and in turn what is a pressure generated here? Our objective is to know what is the pressure in this cavity; when we adding the pressure p 1 10 Newton meter square in the this cavity, left cavity.

Let us we will see now; here when you add the pressure P 1, we know that F 1 by A 1, correct. The pressure is acting over the surface; then what is a F 1? F 1 is 100 Newton; the same 100 Newton what it will produced here, it is transmitted along the stepped piston and it acts on the here in this piston.

But you will see the area difference is there friends. Now, you will see here due to the area difference F 2 by A 2, you will see here how much? 20 Newton per meter square pressure is generated in the right container.

Now, we will see as we are taken the area 2 is to 1, same here doubled; I am adding 10 Newton meter square, I am able to generate 20 Newton meter square. Based on this area, you are multiply the pressure here or you will add here, it will decrease here; anything you will do intensify occasion, you will do.

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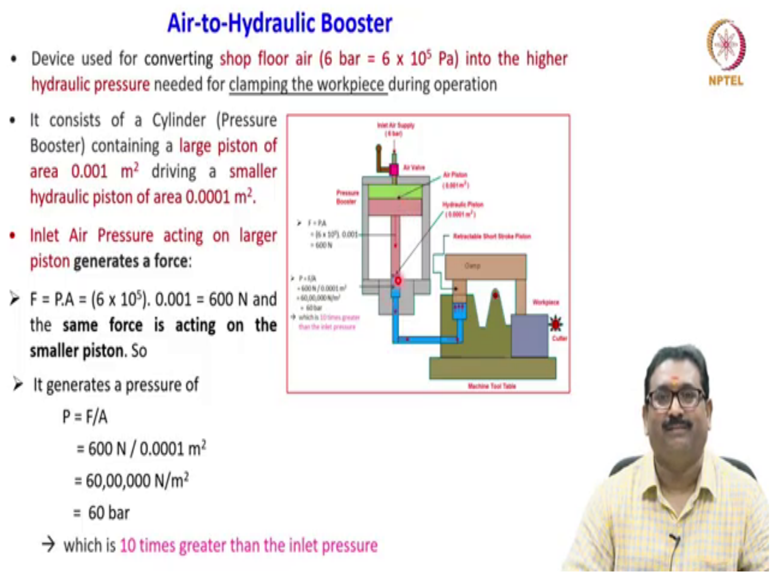

Now, I will show you the simple device used in industry, air to hydraulic booster. It is a device for converting the shop floor air, shop floor air already we know that it is a 6 bar, 6 to 10 bar; I am taking an example here 6 bar it is, bar is already you know that 6 into 10 to the power of 5 Pascal converting into hydraulic higher pressure needed for clamping the workpiece.

Now, what I will do here friends, you will see here it is a stepped piston is there here, is a closed container here again; the one side is connected to liver, I am tapping the air from the shop floor, which is a 6 bar. It is acting on the larger piston, what I will call the air piston; I am taking here is an example 0.001 meter square.

What it will do friends? When the this pressure air pressure will act on this area, it will generate the force 600 Newton. The same 600 Newton is acting on the smaller piston area; how much it is? I am taken 0.0001 meter square.

Then what is the pressure generated here? You will see here, the pressure generated is 60 bar; you will see 6 bar 10 times it is generated pressure here. This 60 bar is used to hold the workpiece through the clamp here; it is a movable up and down clamp during the machining operation, any operations cutting operation, drilling anything.

You will see here the air to hydraulic booster, the air pressure 6 bar is used to generate the large pressure to hold the workpiece during many operations, how it is using the stepped piston. Same thing I explained here friends; the air to hydraulic booster consists of a cylinder with a pressure booster containing the larger piston of area, I am already told you 0.001 meter square driving the smaller hydraulic piston area 0.001 meter square.

These numerical values to understand how the pressure is multiplied, only for that I am taking. Inlet air pressure acting on the larger piston generates the force; as I have told you already force equal to P into A 600 Newton, and the same force is acting on the smaller area here. Then what happens? The areas are different here; it will generate the pressure 60 bar.

This is 10 times greater than the inlet pressure. If you will vary the area of the larger piston to smaller piston, the stepped piston area you will change; you are able to generate the any quantity of pressure is possible in the pressure intensifier air to hydraulic booster what you know it is.

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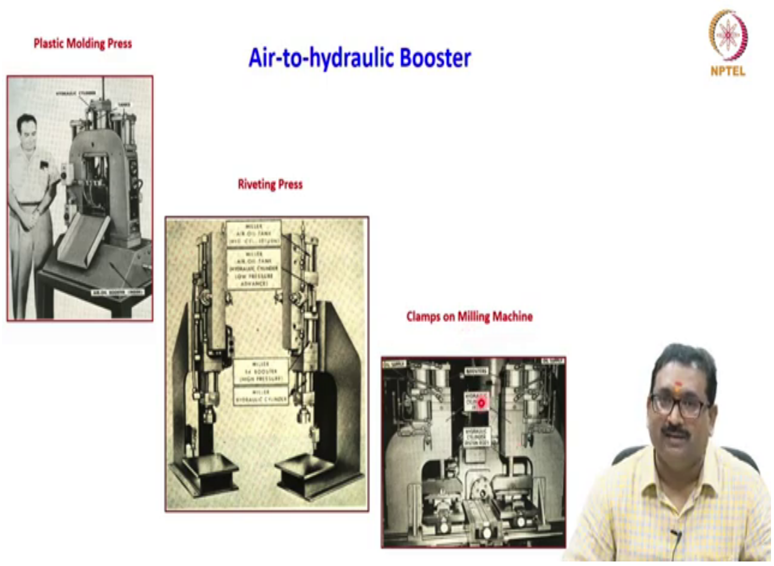

You may ask where are these applications to hold the workpiece all these thing? You see the plastic molding machine, riveting press or you will see the clamps on milling machine; there are various applications are there of the Pascal's for pressure intensification.

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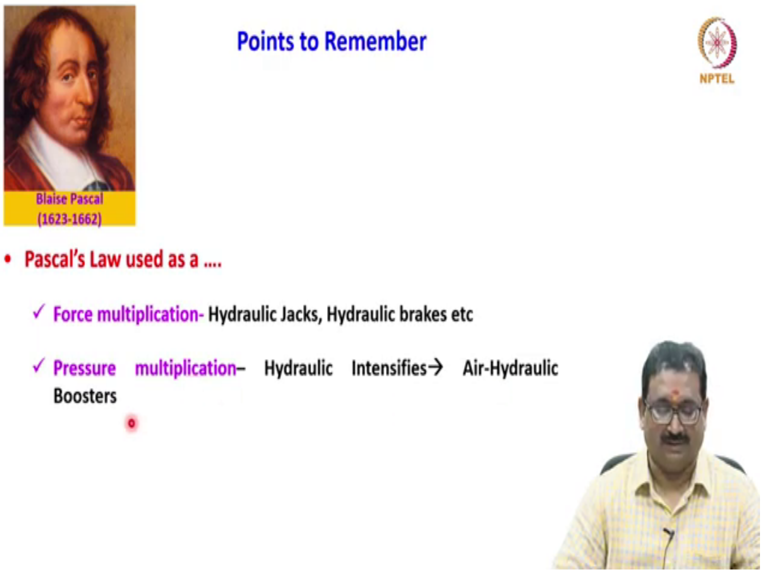

Quickly you will remember some of the points; what I have told you about the Pascal's law, Pascal's law used as a force multiplication. Many devices are there I am listing here; hydraulic jacks or a hydraulic brakes also pressure multiplication, hydraulic intensifier, air to hydraulic boosters.

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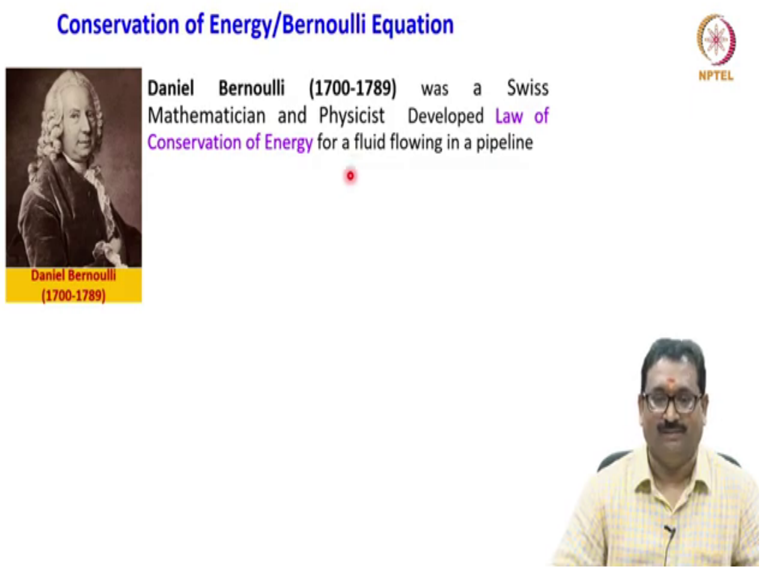

Now, we will move on to one more important law, conservation of energy; here I want to concentrate more on Bernoulli equation. Let us we will see this, Daniel Bernoulli was a Swiss mathematician and a physicist developed a Law of Conservation of energy for a fluid flowing in a pipeline, incompressible fluid water .

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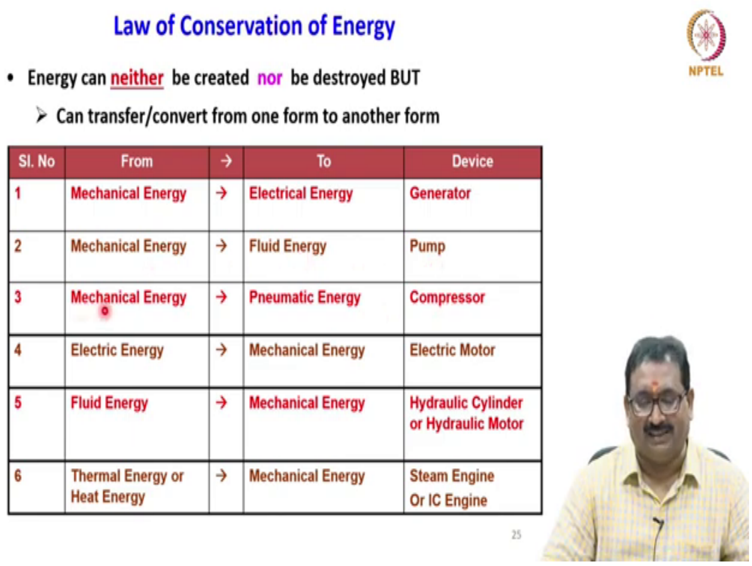

Already we know that, he developed the law of conservation of energy; here energy can neither be created nor destroyed, but can transfer from one form to another form, this is a beauty of the law of conservation of energy.

Meaning, many scientists, many engineers are developing the devices for converting the energy from one to another usable work. I will already told you, the device generator will convert the mechanical energy into electrical energy; similar the hydraulic pump will convert the mechanical energy to fluid energy; compressor mechanical energy into pneumatic energy.

Similarly, the electric motor, electric energy into mechanical energy. Hydraulic cylinder or hydraulic motor what they will do? They will use the fluid energy, either air or incompressible fluid into mechanical energy. Similarly, steam engine or a IC engine, thermal energy or a heat energy into mechanical energy; these are the devices available to convert from one form to another form to do the useful work.

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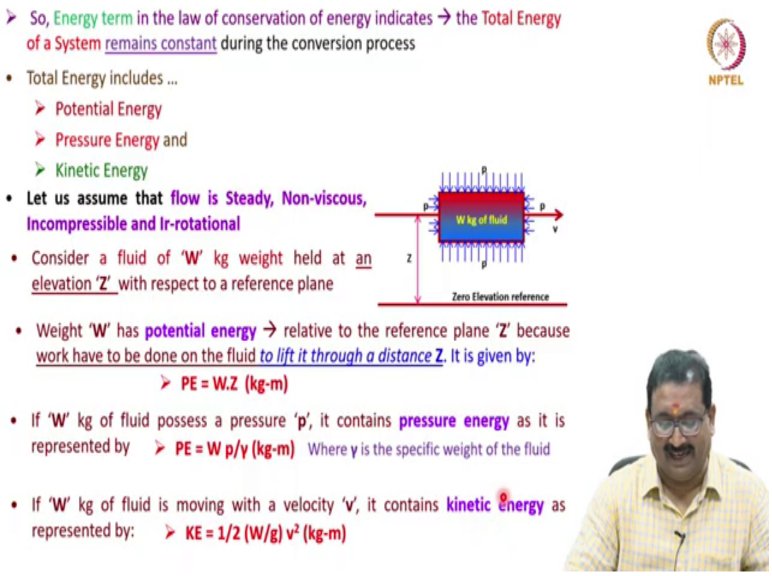

The meaning what this friends law of conservation of energy? The energy term is there correct; energy can neither be created nor be destroyed. Then question arises, what is this energy term? This energy term in the law of conservation of energy indicates the total energy of a system remains constant during the conversion process.

So, the total energy includes the potential energy, the pressure energy and a kinetic energy. To relate this, I will do some simple calculation here; assuming the flow of fluid is steady, non-viscous, incompressible and irrotational. Consider a fluid of W kg weight held at an elevation Z; you will see here, I am lifted the W kg of fluid from the zero reference to Z, I am lifted here.

What happens friend? Weight W has a potential energy relative to the reference plane Z; because work have to be done on the fluid to lift it through the distance Z, because when I will lift the W kg of fluid from zero reference to here work is done on the fluid, which is given by the potential energy W into Z. W is a weight in kgs I am taking here, Z is a distance how much you have moved; work is done here potential energy.

If W kg of fluid possess a pressure P; so it contains the pressure energy as it is represented by pressure energy W into P by specific weight of the fluid, correct. Now, you will see if W kg of fluid is moving with a velocity v, it contains the kinetic energy as represented by kinetic energy equal to half W by g into v square. Meaning, what happens friends? The total energy, meaning potential energy, pressure energy, kinetic energy equal to constant that is a one.

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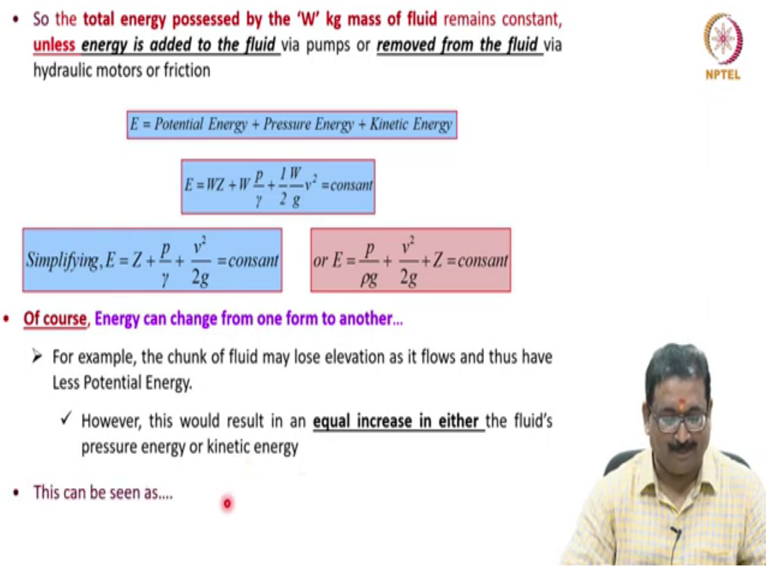

So, the total energy possessed by the w kg of fluid remains constant, unless energy is added to the fluid via pumps or removed from the fluid via the hydraulic motors or a friction. So, the total energy E equal to potential energy plus pressure energy plus kinetic energy. I am substituted the value here, what I have told you in the previous slide. Simplifying this, what I did here simplifying? I divided by w.

Now, I will get Z plus p by gamma plus v square by 2 g equal to constants. Or if you will consider the rho, what happened gamma specific weight know; how you will get? Rho into g, pressure energy p by rho g plus v square by 2 g plus z equal to constant. Of course, energy can change from one form to another form; for example, the chunk of fluid may lose elevation as it flows and thus have a less potential energy.

However, this would result in a equal increase in either the fluids pressure or a kinetic energy. When the fluid will move from higher elevation to lower elevation, the many things may happen; velocity increases or a pressure energy increases. Again you will take at any section, the total energy remains constant; that is a beauty of law of conservation of energy, we will see now it is how it is.

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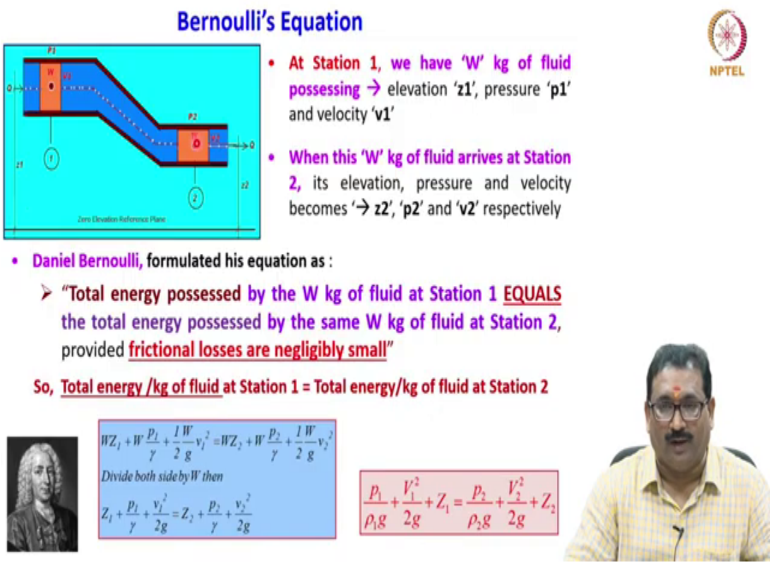

This can be expressed as, I am showing you an example here; the chunk of fluid is at the elevation z 1 from the 0 elevation reference plane. When this chunk of fluid w moves to the station 2; what happens we will see now here. At a station 1, this is station 2; the fluid flowing in the pipe, this is a pipe.

At a station 1, we have a W kg of fluid possessing elevation z 1, pressure energy p 1 and velocity v 1. When this fluid W kg fluid will moves to station 2; what happens, its elevation, pressure and velocity are taken as z 2, p 2, v 2 respectively.

But already we know that, Daniel Bernoulli formulated his equation as total energy possessed by the W kg of fluid at station 1 equals the total energy possessed by the same W kg of fluid at station 2, provided the frictional losses are negligibly small. So, we will write the total energy per kg of fluid at station 1 is equal to total energy per kg of fluid at station 2; that is equal to what it is I am writing here.

Then finally, I will get z 1 plus p 1 by gamma plus v 1 square by 2 g equal to z 2 plus p 2 by gamma plus v 2 square by 2 g, very very simple friends. Or you will write by considering the density p 1 by rho g plus V 1 square by 2 g plus Z 1 is equal to p 2 by rho 2 g plus V 2 square by 2 g plus Z 2, very very simple; meaning the total energy remains same here, even though fluid will move from the higher elevation to lower elevation.

Some of the term increase, some of the term decreases; but total energy remains same when the fluid is flowing in the pipe.

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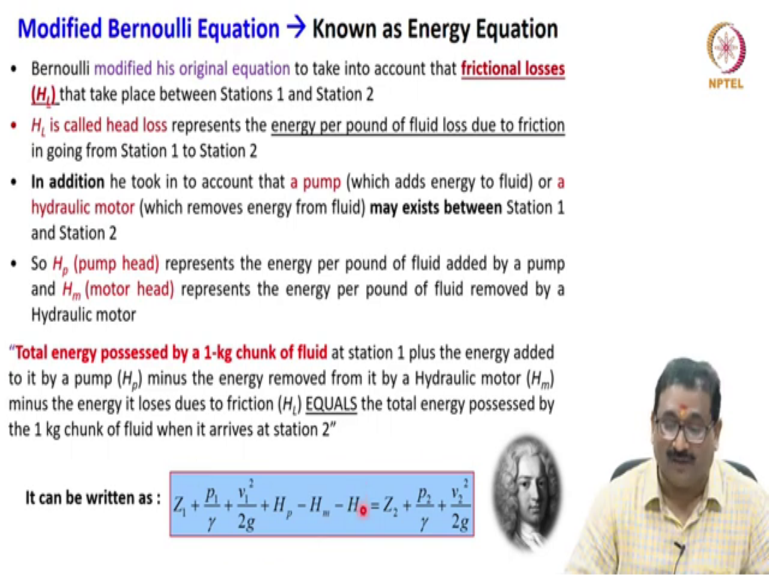

Now, what happens you will see now here friends. The Bernoulli modified his equation by considering the some losses that is what we known as energy equation; I will explain to you how it is now. The Bernoulli modified his original equation what we have seen in the pressure energy, kinetic energy, potential energy equal to constant; only three term he considered, he neglected the friction losses correct, addition of energy he removed.

Now, I am adding here to understand better how Bernoulli considered all the losses and addition of the energy. So, Bernoulli modified his original equation to take into account that frictional losses H L that takes place between the station 1 and 2; because fluid is moving from one to another you know pipe, you know roughness all these we will consider what happened, losses are there, that losses frictional losses I am taking H L.

H L is called the head loss, also when it is moving from h 1 Z 1 to Z 2 what happened; it loses the head loss represents the energy pound of fluid loss due to the friction in going from station 1 to station 2. In addition I am, he took in to account that a pump or a hydraulic motor may exist between the station 1 and 2.

Meaning what I am doing, using the hydraulic pump I am adding the fluid at station 1. And station 2, what I will do? I will tap this energy added through the hydraulic motor, hydraulic motor. Meaning, what I am doing here? I am taking the H p pump head represents the energy per pound of fluid added by the pump H m motor head represents the energy per pound, per kg anything you will take friends here; because it is a SI unit I am taking here.

You know US customer unit I am taking pound, force is in pound; a fluid removed by the hydraulic motor. So, what happened, the total energy possessed by 1 kg of fluid at station 1 plus the energy added to it by the pump H p minus the energy moved from it by the hydraulic motor H m minus the energy it loses due to the friction H L equals the total energy possessed by the 1 kg chunk of fluid when it arrives at station 2.

Meaning here, Bernoulli modified like this here; you see here Z 1 plus p 1 by gamma plus v 1 square by 2 g plus H p adding removing minus H m motor head is equal minus H l loss due to the friction is equal to Z 2 plus p 2 by gamma plus v 2 square by 2 g. This is a what we will call energy equation, which takes into account the pump and motor plus the frictional losses. Please note these friends.