

Oil Hydraulics and Pneumatics
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Basic Laws of Oil Hydraulics and Pneumatics
Lecture – 09

**Part 3 : Applications of Bernoulli Equation-Venturi, Torricellis theorem, Siphon,
Continuity equation and flow configuration, Concept of pressures, Gas laws**

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Application of Bernoulli's Equation



- Venturimeter
- Velocity of fluid flow at the outlet of a Tank
- Siphon

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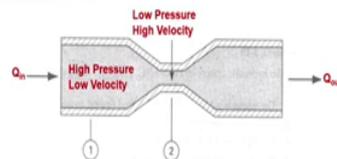
My name is Somashekhar, course faculty for this course. Let us we will move on to the application of this Bernoulli's equation where it is. Already we are seen the venturimeter. Then I am giving you very quickly the velocity of fluid flowing at the outlet of the tank. Also I will give one application practical application as a siphon how Bernoulli's equation is used.

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Application of Bernoulli's Equation



- Venturi used in automobile engine carburetor
- A special pipe whose diameter is gradually reduced until a constant diameter throat is reached and then the pipe gradually increased until it reaches the original size



- Let us write Bernoulli's equation between stations 1 and 2 assuming ideal flow and equal elevations as:

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} = \frac{p_2}{\gamma} + \frac{v_2^2}{2g}; Z_1 = Z_2$$

Solving for $p_1 - p_2$, we have

$$p_1 - p_2 = \frac{\gamma}{2g} (v_2^2 - v_1^2)$$



Let us quickly we will see friends these applications very quickly. The Venturi as we know that the Venturi is a device used in automobile engine carburetor correct. What is this Venturi? A special pipe whose diameter is gradually reduced until a constant diameter throat is reached and then, pipe is gradually increased until it reaches the original size, meaning what it is friend you will see here.

How the pipe is reduced to reach the throat and then again, how increased to get the original diameter. This is figure what I have shown here, it is the Venturi venture it is.

Now, I am showing you here the flow through the Venturi how it is. I am taking the station 1 and station 2. At the station 1 here, I marked Q in; the meaning the quantity of fluid entering here and Q out is a quantity of fluid is existing from the other end meaning what here friends

you will see at the station 1, the fluid energy when it will go here high pressure and low velocity.

When it will move to here middle, low pressure and high velocity it is moving very fast high velocity. Let us we will see now. Let us write Bernoulli's equation between the station 1 and 2. What I will do here? I am applying the Bernoulli's equation at the station 1 and station 2, assuming ideal flow and equal elevation Z_1 , because I am assuming that equal elevation is there meaning Z_1 equal to Z_2 .

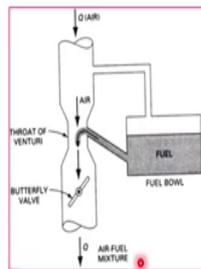
Now, we will see what I did here? Same thing the pressure energy, potential energy, kinetic energy equal in the station 1 and 2, but I am taken Z_1 equal to Z_2 I am removing that term. Now, I am considering only P_1 by γ plus v_1 square by $2g$ equal to p_2 by γ plus v_2 square by $2g$. Solving this what I will get? p_1 γ minus p_2 γ . What I am getting? γ by $2g$ v_2 square minus v_1 square correct.

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Application of Bernoulli's Equation



- Figure shows the **venturi effect** used in an automobile carburetor



- The **volume of air flow** is determined by the opening position of the butterfly valve.
- As the air flows through the venturi, it **speeds up and loses some of its pressure.**
- Pressure in the fuel bowl = the pressure in the air horn above the venturi.
- This **differential pressure** between the fuel bowl and the venturi throat **causes gasoline** to flow into the air stream
- The **reduced pressure** in the venturi helps the **gasoline** to vaporize



Now, I will show you this effect in the automobile carburetor. You will see here what I am showing you here. Automobile carburetor consists of this is a Venturi correct and this is a fuel bowl and this is a throat of Venturi constant diameter and here I am using the butterfly valve to vary the flow. Air fuel mixture is exit now. Let us you will see that. Now, here friends the volume of air flow is determined by the opening position of the butterfly valve.

As the air flows through the Venturi, it speeds up, because the area variations or diameter variations are there it speeds up and loses some of its pressure. Pressure in the bowl is equal to pressure in the air horn above the Venturi air horn above the Venturi. The differential pressure between the fuel in the bowl and the Venturi throat causes the gasoline to flow here ok. Here, differential area difference here it is different, then due to differential area it will flow into the air stream.

The reduced pressure in the Venturi helps the gasoline to vaporize. This is a very very simple the Venturi principle used in the automobile carburetor for proper air fuel mixture. The very very simple principle it is.

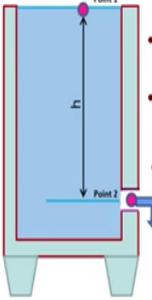
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Torricelli's Theorem



- is a **special case** of Bernoulli's equation that applies to a **liquid draining from a tank** as shown in Figure:



- We want to know the **velocity of fluid flow at the outlet Point 2**
- This can be determined by applying Bernoulli's equation on the **surface of the tank at Point 1** and at the **outlet Point 2**
- Assuming, $P_1 = P_2$, so that these terms may drop out and $v_1 = 0$ as compared to v_2
- Then Bernoulli's equation simplifies to:

$$Z_1 + \frac{v_1^2}{2g} = Z_2 + \frac{v_2^2}{2g}$$

$$Z_1 - Z_2 = \frac{v_2^2}{2g}$$

$$2g(Z_1 - Z_2) = v_2^2$$
- Solving for v_2 , we obtain:

$$v_2 = \sqrt{2g(H_1 - H_2)}$$

- $h = H_1 - H_2$, then Torricelli's Equation/Torricelli's Law becomes: $v_2 = \sqrt{2g h}$
- So the **Discharge velocity depends only on the height of the fluid level above the outlet point and not on the size of the tank**



Now, we will move on to the Torricelli's theorem. Here, is a special case of Bernoulli's equation that applies to a liquid draining from a tank big tank is there you will see very huge tank filled with the incompressible fluid and tapping through this point correct friend.

We want to know what is our objective in the Torricelli's theorem. We want to know the velocity of fluid flow at the outlet point P 2, this is the main objective now. This can be determined by applying the Bernoulli's equation on the surface of the tank at point P 1 and at the outlet point P 2.

What we will do again we will apply the Bernoulli's equation at the point 1 and a point 2. Assuming the P_1 equal to P_2 here, so that these terms may drop out and v_1 is 0 as compared to v_2 here, these are the two assumption's, I am making pressure at here and here equal and the velocity here it is 0 compared to here.

Assuming that the Bernoulli's equations is modified as we know that Z_1 plus P_1 by gamma plus v_1 square by 2 g general Bernoulli equation, but these terms as I have told you know P_1 equal to P_2 these two terms I am canceling.

Similarly, the v_1 square here the velocity at the point 1 is 0 I assumed I removed here. Now, what I will get friends, this after removing the some of the terms Z_1 equal to what happen?

Z_2 plus v_2 square by 2 g, then meaning what it is if I will make the small modification here by taking Z_2 this side Z_1 minus Z_2 equal to v_2 square by 2 g or again, I am making the small manipulation 2 g Z_1 minus Z_2 taking 2 g here v_2 square or what we will do? Solving for the v_2 we obtained v_2 equal to square root of 2 g Z_1 minus Z_2 .

Here, I am head I am taking H_1 h equal to these are the H_1 minus H_2 ok. The h is nothing, but the Z_1 minus Z_2 . Then, the Torricelli's equation or a Torricelli's law becomes v_2 equal to square root of 2 g h. This is very very important. The velocity at the exit is equal to square root of 2 g h; h is a Z_1 minus Z_2 it is.

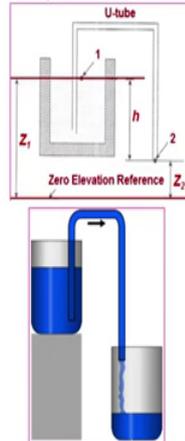
So, the discharge velocity depends only on the height of the fluid level above the outlet point and not on the size of the tank. Size of the tank does not matter here very large tank filled with liquid incompressible fluid correct. You will see here the velocity at the exit does not depend on any geometry of the tank only it depends upon the h, h is the differential h.

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Siphon



- Siphon is a familiar hydraulic device, commonly used to → cause a fluid to flow from one container in an upward direction over an obstacle and then flow downwards into a second lower container as shown in Figure below:
- When siphoning gasoline from an automobile gas tank → a person can develop the suction pressure by momentarily sucking on the free end of the hose
- This allows atmospheric pressure in the tank to push the gasoline up the U-tube as required
- For continuous flow operation, the free end of the U-tube must lie below the gasoline level in the tank



Now, we will move on to the device what we will call the siphon. What is this siphon friend? Siphon is a familiar hydraulic device, commonly used to cause a fluid to flow from one container in an upward direction. You will see here from two containers are there here this is a siphon; siphon is a tube you will see here siphon is a tube used to cause a fluid flow from one container to another container and over the obstacle means here it is U-tube know U-tube, then flow downwards into the second container.

Similarly, see here same figure I represented here schematically, siphon is a this is a siphon the U-tube. U-tube is a siphon to tap the fluid from this tank to downwards. When the siphoning a gasoline from an automobile gas tank what the person will do? A person can develop a suction pressure by momentarily sucking on the free end of the hose. What he will do?

He will put this U-tube in the tank, then he will apply here suction he will push it then fluid once it will catch continuously it will move until it will drain off. This allows the atmospheric pressure acting on this and here vacuum differential pressure is there, then it will catch up the fluid. Continuous flow operation, the free end of the U-tube must below the gasoline level of the tank.

Please remember this is the free end; one end is in the U-tube in the tank another one is this Z 2 is very important. Here, zero reference from the top it is Z 1 here I am taking the free end is it is Z 2 meaning small h equal to what Z 1 minus Z 2. Similarly, previous what I have told you.

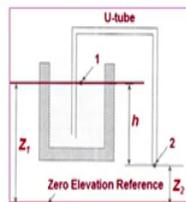
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Siphon

- We can analyze the flow through a siphon by applying the energy equation at Point 1 and Point 2 :

$$Z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} + H_p - H_m - H_L = Z_2 + \frac{p_2}{\gamma} + \frac{v_2^2}{2g}$$
- The following conditions apply for the siphon:
 - $p_1 = p_2 \rightarrow$ Atmospheric pressure
 - Surface area of the fluid in the container is large, so that the velocity $v_1 = 0$
 - There is no pump or motor ($H_p = H_m = 0$)
 - $Z_1 - Z_2 = h$
- Then above equation is identical to Torricelli's equation

$$v_2 = \sqrt{2g(Z_1 - Z_2 - H_L)} = \sqrt{2g(h - H_L)}$$



So, we can analyze the flow through the siphon by applying the same Bernoulli equation at point 1 and point 2. Same what is that? As we know that here I am considering loss this is Z 1

plus P_1 by γ plus v_1 square by $2g$ I am having I am adding here some of the terms. The following conditions apply for the siphon the p_1 equal to p_2 atmospheric pressure acting on the container as well as here.

Surface area of the fluid in the container is very large. So, that v_1 is 0 as I have told you in the previous slide.

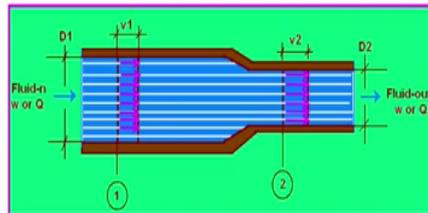
Therefore, no pump or no motor that is why I am telling here I considered here, but you do not all neglect all the frictional losses H_p equal H_m is equal to 0, then Z_1 minus Z_2 you will see here Z_1 minus Z_2 is small h . The above equation is identical to Torricelli's equation and after doing all the some manipulations all. What you will get? v_2 equal to similarly $2g(Z_1 - Z_2)$ meaning here.

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Continuity Equation



- "For steady flow in a pipe line \rightarrow the weight flow rate is the same for all locations of the pipe"



- So the flow rate at the Section 1 and Section 2:

$w_1 = w_2$ $\gamma_1 A_1 v_1 = \gamma_2 A_2 v_2$ where γ = specific weight of fluid A_1 and A_2 = cross-sectional areas of pipe at 1 & 2 v_1 & v_2 = velocity of fluid at 1 & 2	Volume flow rate : $Q_1 = Q_2$ $A_1 v_1 = A_2 v_2$
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I will get the same equation what we have seen in the flow through the tank at the exits. Now, friends we will move on to one more principle generally used in oil hydraulics and pneumatics popularly continuity equation.

What is this continuity equation? "For steady flow in a pipe line - the weight flow rate is the same for all the location of the pipe" meaning I am considered here the pipe having different diameters here correct. Now, what I have shown here D_1 is a bigger diameter D_2 is a smaller diameter fluid is entering here and fluid is exiting here.

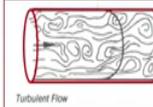
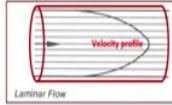
You will take any section free here friends the weight flow rate remains constant. How it is? So, the flow rate at section 1 and section 2 the weight flow rate is constant as I have told you according to continuity equation for the streamline flow in the pipeline meaning what it is w_1 equal to w_2 that is equal to $\gamma_1 A_1 v_1 = \gamma_2 A_2 v_2$.

If γ is a specific weight of the fluid and A_1 and A_2 are the cross sectional area at the pipe at section 1 and section 2; v_1 and v_2 are the velocities of the fluid at station 1 and station 2 or the volume flow rate is equal at any section friends any section you will take the volume flow rate or weight flow rate both are same equal. Q_1 equal to Q_2 ; that is what $A_1 v_1$ equal to $A_2 v_2$ this is known as the continuity equation. These are even though very simple they are very important in oil hydraulics and pneumatics.

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Flow Configuration

- **Laminar Flow and Turbulent Flow**
- **Laminar flow or Viscous flow** → smooth and layered flow → particles move along well defined paths or stream lines and all the stream lines are straight and parallel
- **Turbulent Flow** → not smooth and not layered pattern → particles move in zig-zag paths (Chaotic fashion → churning action) → eddies formation takes place which are responsible for high energy loss.
- Reynolds Number ($Re = VD/\nu$) → If the Re is less than 2000 → Laminar ; If Re is more than 4000 → Turbulent and Re lies between 2000 and 4000 → the flow may be laminar or turbulent



Now, let us quickly we will see the flow configurations. As we know in fluid mechanics laminar flow and turbulent flow; these are very important. Please brush up all these things. What is laminar flow?

Laminar flow or a viscous flow it is known as a smooth and a layered flow see here smooth and layered flow particles move along a well defined paths or a stream lines and all the stream lines are straight and parallel you will see here straight and parallel you will see the velocity profile also here in the laminar flow.

Next one is a turbulent flow. Here, it is not smooth and a not layered pattern you will see the pattern here flow path pattern particles move in a zig-zag paths meaning a chaotic paths, what

you will it will creates in the churning actions meaning eddy formation eddies formation takes place which are responsible for high energy loss.

But most of the derivation we people are assuming the laminar flows, because here losses are more in turbulent flows, but to understand the laminar and turbulent flow we must know the one more term what we will call Reynolds number. Reynolds number Re equal to VD by μ .

If there is Reynolds number is less than 2000, the flow is termed as laminar flow. If Re is more than 4000, the flow is turbulent. If Re is lies between the 2000 and 4000, the flow may be laminar or turbulent.

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Concept of Pressure → Relate to 4 Important Pressure Terms



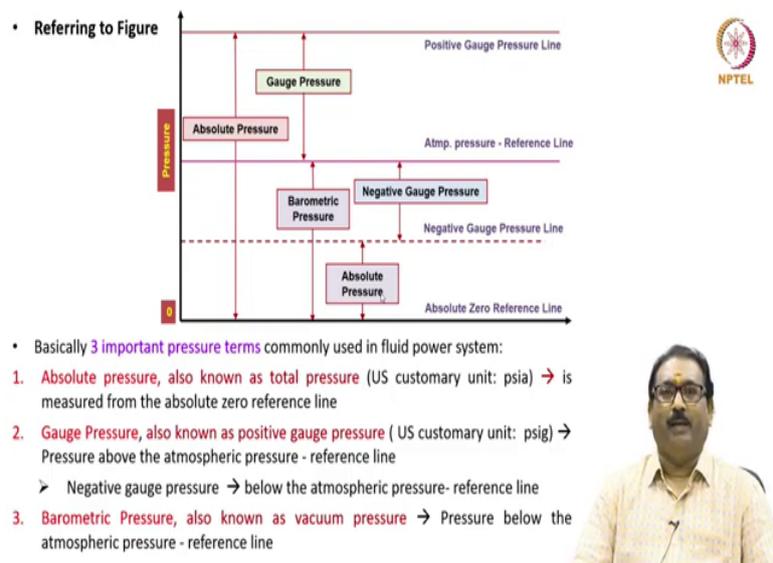
- Atmospheric Pressure
- Gauge Pressure
- Vacuum Pressure
- Absolute Pressure



Now, quickly we will see some of the terms associated with the pressure. In oil hydraulics, already we know that incompressible fluid pressure P we are using P is proportional to h height of the fluid irrespective of the container size what we have seen.

But now, I will give you the some of the important terms which are very essential in the pneumatics. The four important terms I am telling you now. One is called atmospheric pressure, gauge pressure, vacuum pressure, absolute pressure.

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As we have seen the four important terms of the pressure. Now, we will see these pressure terms referring to the figure. Here I have shown the x y graph in which absolute zero reference is marked and then, atmospheric pressure reference line and above the atmospheric

pressure reference line I have marked positive gauge pressure line and below this I have marked negative gauge pressure line.

Always you will remember friends, the pressures are generally specified with respect to the atmospheric pressure reference line which is generally the one bar or the absolute zero reference line. Let us we will see the 3 important pressure terms commonly used in fluid power system.

1st one is absolute pressure also known as a total pressure US customary unit for this is psia meaning pounds per square inch absolute is measured from the absolute zero reference line. How it is you will see here absolute pressure total pressure is always measured from the absolute zero reference line.

Next one is a gauge pressure also known as a positive gauge pressure, in US customary unit it is a psig, pounds per square inch; g is a gauge. This is pressure above the atmospheric pressure reference line.

Here, you will see above this is a gauge pressure. Sometimes, it is known as the positive gauge pressure as because one more term is there negative gauge pressure which is measured below the atmospheric pressure reference line meaning here you will get minus 0.3 psig meaning it is a negative gauge pressure always measured with atmospheric pressure reference line.

3rd one is a barometric pressure also known as a vacuum pressure, pressure below the atmospheric pressure reference line always it is a barometric pressure or a vacuum pressure which is below the atmospheric pressure. So, in one word all the pressures generally specified with respect to the atmospheric pressure reference line which is generally the one bar above.

It is called with respect to this above it is called the gauge pressure or positive gauge pressure below this line is a negative gauge pressure which is nothing, but also the barometric pressure

or a vacuum pressure. Then from the absolute zero reference line from the top it is always it is a absolute pressure.

You will see here also one more I have marked here the absolute pressure. Here, you will see even though it is below the atmospheric pressure line if you will measure with respect to the absolute zero reference line, it is known as absolute pressure. For example, its value maybe 0.7. Also you will remember friends, the pressure units in SI unit is generally people are using the Pascal, kilo Pascal, mega Pascal and bar.

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Classification of Pressure Measuring Instruments

- **Moderate Pressure Measurement can be carried out using...**
 1. **Manometer** → used generally for Static pressure
 - uses glass tube filled with water or mercury
 - U-tube manometer
 - Well type or Reservoir type or Cistern manometers
 - Bent type manometers
 - Mechanical displacement type : Ring balance manometer and Bell-type manometer
 2. **Elastic Pressure Transducers** → used for both Static and dynamic pressure – Uses Elastic Elements
 - Bourdon tube pressure gauge
 - Diaphragm type pressure gauge
 - Bellow type pressure gauge
 - Capsules type pressure gauge
 - Spiral type pressure gauge
 - Helix type pressure gauge
- **Very High Pressure Measurement can be carried out using...**
 - Electric gauges - based on resistance change of Manganin or Gold-chrome wire
- **High Vacuum Measurement can be carried out using...**
 - McLeod gauge
 - Thermal conductivity gauge or Pirani gauge
 - Ionization gauge
 - Knudsen gauge



Now, I will give you quickly some of the measuring devices for the different types of pressures. They are classified under different categories. Now, I will tell you the moderate pressure measurement can be carried out using the manometers used generally for the static pressure which uses the glass tube filled with water or mercury.

Here, different types are there in manometer U-tube manometer, well type or a reservoir type or a cistern manometers or a bent type manometers, mechanical displacement type here ring balance manometers and a bell-type manometers. And another classification here is elastic pressure transducers for measuring the moderate pressure used for both static and dynamic pressure. This manometers are only static pressure here for both static and dynamic pressure which uses the elastic elements.

Based on this bourdon tube pressure gauge, diaphragm type pressure gauge, bellow type pressure gauge, capsules type pressure gauge or spiral type pressure gauge, helix type pressure gauge. There are various categories are there in the elastic pressure transducers for measuring the moderate pressure measurement.

Electrical pressure transducers for measuring the moderate pressure. Here, resistance-type pressure gauge, potentiometric devices, inductive type pressure type transducers, capacitive type transducers, piezoelectric pressure transducer; these are for the moderate pressure measurement. You will see if we want to measure a very high pressure measurement can be carried out using the electric gauges based on resistance change of manganin or a gold-chrome wire.

The high vacuum measurement can be carried out using McLeod gauge, thermal conductivity gauge or it is also known as Pirani gauge, ionization gauge, Knudsen gauge. Please understand friends, there are various types of pressure measurement devices are there to measure the moderate pressure, very high pressure and a very high vacuum.

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Indicative Pressure Range of Instruments



- **Below 1 mm of Hg**
 - Manometers and low pressure gauges
- **Between 1 mm of Hg to 1000 atm**
 - Bourdon tubes
 - Diaphragm gauges
 - Bellows
- **High Pressure (1000 atm and above)**
 - Electrical resistance type
- **Very low Pressure or High Vacuum (up to 10^{-9} torr)**
 - McLeod gauge
 - Thermal conductivity gauge or Pirani gauge
 - Ionization gauge



Now, I required the indicative pressure range for the instrument correct. Now, we will see below 1 mm of Hg, we are using the manometers and a low pressure gauges. Between 1 mm of Hg to 1000 atmospheric, bourdon tubes, diaphragm gauge, bellows. High pressure means 1000 atmosphere and above. We are using the electrical resistance type, very low pressure or high vacuum up to 10 to the power of minus 9 torr.

We are using McLeod gauge, thermal conductivity gauge or a Pirani gauge, ionization gauge. There are various instruments are there for measuring the different level of pressures.

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Gas Laws

• 16th Century Scientists have discovered the laws to relate the interactions between the gas parameters → **Temperature (T)**, **Pressure (P)**, and **Volume (V)** as

$P_2 > P_1; V_2 < V_1; T_2 > T_1$

1. Boyle's Law → P and V [T=CONST.]
2. Charles' Law → V and T [P=CONST.]
3. Gay-Lussac's Law → P and T [V=CONST.]
4. General Gas Law → P, V and T



Now, quickly we will go to the gas laws which are very essential to understand the pneumatics. Here, 16th century the scientist have discovered the laws to relate the interactions between the gas parameters; Temperature T, Pressure P, Volume V as we know that here friends in 16th century scientists are studied when we are taking the closed contained gas assumed to be air.

Then fitted with the piston when we will push this by using the pressure F 1, they are studying what happens to the gas inside the cylinder. What happened to pressure inside the cylinder, what happened to volume, what happened to the temperature? The people are studied these gas parameter pressure, volume and temperature inside the closed container.

What happened? If we will push this piston inside the cylinder. What happened? Pressure increases P 2 is greater than P 1 what it is inside previously and volume decreases; whatever

the large volume here when piston moves down volume decreases, but you will remember temperature also increases. You will see friends what happened to the gas parameter when we will push the gas inside the cylinder the pressure increases, volume decreases and temperature increases.

Then based on this the different scientists are studied by keeping one parameter constant and varying two parameters. Here, you will see the Boyle's law, he kept temperature constant and he studied what happens to pressure and volume inside the container. Charles law relates to the volume and temperature, if we will keep the pressure constant. What happens similarly Gay-Lussac's he studied the relationship between the P and T pressure and T temperature when volume constant. The general gas law is one which relates to pressure, volume and temperature.

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Boyle's Law → Constant Temperature Process

• If temperature remains constant → the pressure of a confined mass of gas will vary **INVERSELY** with its volume.

• Mathematically :

$$P \propto \frac{1}{V}$$

$$PV = \text{constant}$$

$$P_1V_1 = P_2V_2 = P_3V_3 \dots P_nV_n$$

$$\frac{V_2}{V_1} = \frac{P_1}{P_2}$$

$$\frac{V_3}{V_1} = \frac{P_1}{P_3}$$

• Experiment

Constant Temperature Compression

$T_1 = T_2$

$P_2 > P_1$

$V_2 < V_1$

Let us quickly we will see these friends the Boyle's law what we known as constant temperature processes it is. If temperature remains constant, the pressure of a confined mass of gas will vary INVERSELY with its volume. So, mathematically, it is represented P is inversely proportional to 1 over V; that is equal to P V equal to constant meaning anywhere you will take any number P 1 V 1 equal to P 2 V 2 that is equal to P 3 V 3 or V 1 by V 2 equal to P 2 by P 1.

How he did experiment? He took the air in the container and he fitted with piston and push rod. When we will push this what happens, as I have told you T 1 equal to T 2 it is a constant temperature process he maintained and the F 2 is greater than F 1 and V 2 is less than V 1. It is a constant temperature compression process.

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Charles' Law → Constant Pressure process

• If pressure remains constant → the volume of a confined mass of gas will vary **DIRECTLY** with Absolute temperature.

• Mathematically:

$$V \propto T$$

$$\frac{V}{T} = \text{constant}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = \frac{V_3}{T_3} = \dots = \frac{V_n}{T_n}$$

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

$P_1 = P_2$ $T_2 > T_1$
 $V_2 < V_1$ $W \text{ is Constant}$

The Charles law here: Constant pressure processes constant pressure; if the pressure remains constant what happens to the volume and the temperature the volume of a confined mass of gas will vary DIRECTLY with absolute temperature. Mathematically, V is directly proportional to T or V by T equal to constant or V_1 by T_1 equal to V_2 by T_2 V_3 by T_3 equal or V_1 by V_2 equal to T_1 by T_2 .

How he did here. You will see here instead of applying the force varying force on the piston, he kept the known weight on the piston then he studied what happens to the volume what happens to the temperature.

Keeping the P_1 equal to P_2 . How he generated the pressure here constant? By keeping the known weight over the piston. He studied what happens to my volume decreases automatically and temperature increases. It is a constant pressure heat addition. What he did here friends? He added the heat here correct.

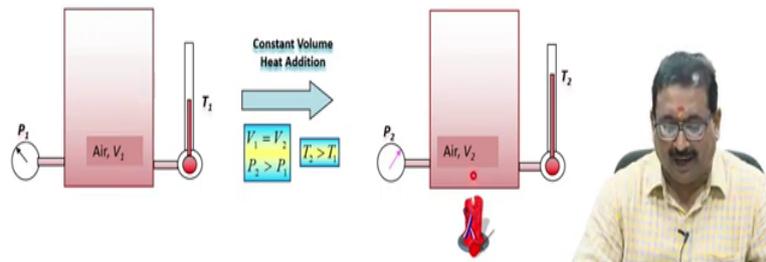
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Gay-Lussac's Law → Constant Volume Process



- If **volume remains constant** → the pressure of a confined mass of gas will vary **DIRECTLY** with Absolute temperature.

- Mathematically:
$$\frac{P \propto T}{T} = \text{constant}$$
$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = \frac{P_3}{T_3} = \frac{P_4}{T_4}$$
$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$



The Gay-Lussac's law- constant volume process friends. Volume remains constant, then what happens to P and T. If volume remains constant, the pressure of a confined mass of gas will vary **DIRECTLY** with the absolute temperature. Mathematically, P is proportional to T or P by T equal to constant or P 1 by P 2 equal to T 1 by T 2. How he did here. He took only the cylinder filled with the air V 1.

Then what he is doing constant volume know what he is doing now, he goes on adding the heat here. Then he is studying what happens to my P 2 and T 2. Yes, P 2 increases and T 2 also increases. This is a constant volume heat addition heat addition it is.

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General Gas Law



- Contains all the gas parameters \rightarrow T, P and V, since none are held constant during process from state 1 to state 2.
- Boyle's, Charles', and Gay-Lussac's Laws can be combined into a single gas law, as defined mathematically by

$$\frac{PV}{T} = mR$$

$m = \text{mass of the gas (kg)}$
 $R = \text{gas constant} \Rightarrow \text{the amount of work required to raise 1 kg mass of gas through one degree kelvin}$

$$\frac{PV_1}{T_1} = \frac{PV_2}{T_2} = \frac{PV_3}{T_3} = \dots = \frac{PV_n}{T_n}$$

- Is used to size gas-loaded accumulator



Last, but not the least. The general gas law relates to all the gas parameter temperature, pressure, volume. Here, since none are held constant during the process from state 1 to state 2.

The Boyle's law, Charles law, Gay-Lussac's law can be combined into the gas law. As defined mathematically as $P V$ by T equal to $m R$ or simply we will call it a $P V$ equal to $m R$ T also very easy it is; m is a mass of the gas, R is a what we will call a gas constant. This is very important to relate all the parameter used in sizing the gas-loaded accumulator ok.

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Concluding Remarks



- Today we have discussed the some basics of fluid mechanics which are essentials to understand the course Oil hydraulics and Pneumatics better
- We have discussed today **Hydro-mechanics** , **Laws related to Hydraulics** : **Pascal's Law and its applications**, **Law of conservation of Energy – Bernoulli's theorem**, **Energy Equation and its applications**, **Continuity Equation**, **Flow Configurations** , **Laws Related to Pneumatics- Gas Laws**
- Ok. We will stop Now
- Let us meet in Next Class – to study in detail Fluid Power Symbols- very much essential to construct and understand the Fluid Power Circuits
- Until then Bye Bye..,



You already brushed up many basics of fluid mechanics. I am requesting all the students brush up all the things once again what you have studied in the lower semester in fluid mechanics, if not you will brush up using the various textbooks. These are very very fundamentals to learn the oil hydraulics and pneumatics. So, I will conclude today's lecture. Today we have discussed the some basics of fluid mechanics which are essentials to understand the course oil hydraulics and pneumatics better.

We have discussed the hydro-mechanics, laws related to hydraulics. Here, we have studied the Pascal's law and its applications, law of conservation of energy, Bernoulli theorem, energy equation and its applications, continuity equation, flow configurations then laws related to pneumatics, all gas laws.

Friends we will stop now. Let us we will meet in the next class to study the detailed fluid power symbols; very much essential to construct and to understand the fluid power circuits during the course until then bye.

Thank you one and all for your kind attention [FL].

Thank you.