What is the basic difference between a compressor and a pump?

Pumps are used to transport liquids by pressurizing them, from a source either above or below the pump to any destination point of any height. They cannot transfer gases , and will be in a state of dangerous malfunction if they are transporting a liquid at its boiling point(explosion of pump - see **Cavitation** in **Wikipedia**). A pump is governed by the **suction head** , which is the equivalent of depth from which a liquid has to be pumped , and a **delivery head** , which is the equivalent pressure head expressed in meters that is needed to pump the liquid to its destination against gravity , pipe friction and pipe bends, and slopes or heights.

A compressor, is used to increase pressure of a fluid , and is used just like a pump in the way of transporting gases , or pressurizing them for some chemical or mechanical operations. A compressor is governed by what is called as a **compression ratio** , which is the ratio of output pressure to input pressure. The compression ratio is always greater than one , and usually there are "multi-stage compressors" which progressively increase the gas pressure in each stage of compression.

Reynolds Number

The Reynolds number is the ratio of inertial forces to viscous forces and is a convenient parameter for predicting if a flow condition will be laminar or turbulent. It can be interpreted that when the viscous forces are dominant (slow flow, low Re) they are sufficient enough to keep all the fluid particles in line, then the flow is laminar. Even very low Re indicates viscous creeping motion, where inertia effects are negligible. When the inertial forces dominate over the viscous forces (when the fluid is flowing faster and Re is larger) then the flow is turbulent.

Bernoulli's principle

It states that an increase in the velocity(v) of a fluid occurs simultaneously with a decrease in pressure(p) or a decrease in the fluid's potential energy(gz) (where g=acceleration due to gravity,(z)or(h)=height ".

"Bernoulli's principle states that as a fluid moves around an object it creates different pressures on that object".

When the velocity of fluid is more the pressure tends to be less and the vice versa as we know pressure and velocity are inversely proportional

This principle is generally known as the **conservation of energy principle** and states that the **total energy** of an isolated system remains constant — it is said to be conserved over time.

Bernoulli's equation

It can be considered to be a statement of the **conservation of energy principle** appropriate for flowing fluids. It is one of the most important/useful equations in **fluid mechanics**. It puts into a relation **pressure and velocity** in an **inviscid incompressible flow**. **Bernoulli's equation** has some restrictions in its applicability, they summarized in following points:

- steady flow system,
- density is constant (which also means the fluid is incompressible),
- no work is done on or by the fluid,
- no heat is transferred to or from the fluid,
- no change occurs in the internal energy,
- the equation relates the states at two points along a single streamline (not conditions on two different streamlines)

Under these conditions, the general energy equation is simplified to:

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Flow rate

Quantity of a gas or liquid moving through a pipe or channel within a given or standard period (usually a minute or hour). To review, flowing fluids are characterized by a quantity called the flow rate, which is defined as the volume of fluid flowing through an area each second. In a pipe or other enclosed region, the flow rate can be expressed in terms of the fluid speed and the cross-sectional area of the pipe.

Q=A x V

Laws of Thermodynamics

The First Law of Thermodynamics

The first law of thermodynamics, also known as Law of Conservation of Energy, states that energy can neither be created nor destroyed; energy can only be transferred or changed from one form to another. For example, turning on a light would seem to produce energy; however, it is electrical energy that is converted.

A way of expressing the first law of thermodynamics is that any change in the internal energy (ΔE) of a system is given by the sum of the heat (q) that flows across its boundaries and the work (w) done on the system by the surroundings:

$\Delta E=q+w\Delta E=q+w$

This law says that there are two kinds of processes, heat and work, that can lead to a change in the internal energy of a system. Since both heat and work can be measured and quantified, this is the same as saying that any change in the energy of a system must result in a corresponding change in the energy of the surroundings outside the system. In other words, energy cannot be created or destroyed. If heat flows into a system or the surroundings do work on it, the internal energy increases and the sign of q and w are positive. Conversely, heat flow out of the system or work done by the system (on the surroundings) will be at the expense of the internal energy, and q and w will therefore be negative.

The Second Law of Thermodynamics

The second law of thermodynamics says that the entropy of any isolated system always increases. Isolated systems spontaneously evolve towards thermal equilibrium—the state of

maximum entropy of the system. More simply put: the entropy of the universe (the ultimate isolated system) only increases and never decreases.

A simple way to think of the second law of thermodynamics is that a room, if not cleaned and tidied, will invariably become more messy and disorderly with time – regardless of how careful one is to keep it clean. When the room is cleaned, its entropy decreases, but the effort to clean it has resulted in an increase in entropy outside the room that exceeds the entropy lost.

The Third Law of Thermodynamics

The third law of thermodynamics states that the entropy of a system approaches a constant value as the temperature approaches absolute zero. The entropy of a system at absolute zero is typically zero, and in all cases is determined only by the number of different ground states it has. Specifically, the entropy of a pure crystalline substance (perfect order) at absolute zero temperature is zero. This statement holds true if the perfect crystal has only one state with minimum energy.

Laws of thermodynamics

The four laws of thermodynamics define fundamental physical quantities (temperature, energy, and entropy) that characterize thermodynamic systems at thermal equilibrium. The laws describe how these quantities behave under various circumstances, and forbid certain phenomena (such as perpetual motion).

The four laws of thermodynamics are:[1][2][3][4][5]

- Zeroth law of thermodynamics: If two systems are in thermal equilibrium with a third system, they are in thermal equilibrium with each other. This law helps define the concept of temperature.
- First law of thermodynamics: When energy passes, as work, as heat, or with matter, into or out from a system, the system's internal energy changes in accord with the law of conservation of energy. Equivalently, perpetual motion machines of the first kind (machines that produce work with no energy input) are impossible.

- Second law of thermodynamics: In a natural thermodynamic process, the sum of the entropies of the interacting thermodynamic systems increases. Equivalently, perpetual motion machines of the second kind (machines that spontaneously convert thermal energy into mechanical work) are impossible.
- Third law of thermodynamics: The entropy of a system approaches a constant value as the temperature approaches absolute zero.[2] With the exception of non-crystalline solids (glasses) the entropy of a system at absolute zero is typically close to zero, and is equal to the natural logarithm of the product of the quantum ground states.

There have been suggestions of additional laws, but none of them achieves the generality of the four accepted laws, and they are not mentioned in standard textbooks

Types of flow

Three different types of fluid flow are written in brief under

1. Laminar flow
2. Turbulent flow
3. Transitional flow

1. Laminar flow:

Occurs when the fluid flows in parallel layers, with no mixing between the layers. Where the center part of the pipe flow the fastest and the cylinder touching the pipe isn't moving at all.

The flow is laminar when Reynolds number is less than 2300.

2. Turbulent flow:

In turbulent flow occurs when the liquid is moving fast with mixing between layers. The speed of the fluid at a point is continuously undergoing changes in both magnitude and direction.

The flow is turbulent when Reynolds number greater than 4000.

3. Transitional flow:

Transitional flow is a mixture of laminar and turbulent flow, with turbulence flow in the center of the pipe and laminar flow near the edges of the pipe. Each of these flows behaves in different manners in terms of their frictional energy loss while flowing and have different equations that predict their behavior.

The flow is transitional when Reynolds number is in between 2300 and 4000.

Classification of Fluid Flow – Based on Flow Pattern

Fluid flow can be steady or unsteady, depending on the fluid's velocity:

- **Steady.** In steady fluid flow, the velocity of the fluid is constant at any point.
- **Unsteady.** When the flow is unsteady, the fluid's velocity can differ between any two points.

- **Rotational or Irrotational Flow**
  To classify any flow as Rotational or Irrotational the angular motion of the fluid elements is analyzed. If the angle between the two intersecting lines of the boundary of the fluid element changes while moving in the flow, then the flow is a Rotational Flow. But if the fluid element rotates as a whole and there is no change in angles between the boundary lines then the flow cannot be Rotational Flow, so it is Irrotational Flow.

This means that there should be some deformation in the fluid element in a Rotational Flow. Such deformation of the fluid element or the shear strain is necessarily caused by tangential forces or shear stresses. Shear stresses are caused by viscosity, thus the flow of viscous fluids is rotational. But this does not mean that the flow of non-viscous or ideal fluid is always irrotational. The flow of ideal fluids can be rotational by external work or heat interaction.

Laminar or Turbulent Flow
Laminar Flow

The flow of a fluid moving with a moderate speed has fluid layers moving past other layers as if some sheets are moving over other layers. Such flow of fluids is called Laminar Flow.

In Laminar Flow viscous shear stresses act between these layers of the fluid which defines the velociity distribution among these layers of flow. In Laminar Flows the shear stresses are defined by Newton's equation for shear stress.

- **Turbulent Flow**
  As the flow speed of the otherwise calm layers increases, these smoothly moving layers start moving randomly, and with further increase in flow velocity, the flow of fluid particles becomes completely random and no such laminar layers exist any more. Shear stresses in the Turbulent Flow are more than those in Laminar Flow.

  A dimensionless parameter, Reynolds Number, is defined as the ratio of inertial and viscous force to characterize these two types of flow patterns. With increase in flow velocity the initial forces increase so the Reynolds Number. For moderate flows the Reynolds Number is below 2000 and for Turbulent Flows it is well above 2300. For the transition region between the two types the Reynolds Number varies between 2000-4000.

Three Types of Heat Transfers

Second Law of Thermodynamics

The Second Law of Thermodynamics states that heat transfers from an object of a higher temperature to that of a lower temperature. The higher energy atoms (and thus higher temperature) move toward the lower energy atoms (lower temperature) in order to maintain equilibrium (known as thermal equilibrium). Heat transfer occurs in order to maintain this principle when an object is at a different temperature from another object or its surroundings.

Heat Transfer by Conduction

When particles of matter are in direct contact, heat transfers by means of conduction. The adjacent atoms of higher energy vibrate against one another, which transfers the higher energy to the lower energy, or higher temperature to lower temperature. That is, atoms of higher intensity

and higher heat will vibrate, thereby moving the electrons to areas of lower intensity and lower heat. Fluids and gases are less conductive than solids (metals are the best conductors) due to the fact that they are less dense, meaning that there is a larger distance between atoms.

Convection Heat Transfer

Convection describes heat transfer between a surface and a liquid or gas in motion. As the fluid or gas travels faster, the convective heat transfer increases. Two types of convection are natural convection and forced convection. In natural convection, fluid motion results from the hot atoms in the fluid, where the hot atoms move upwards toward the cooler atoms in the air--the fluid moves under the influence of gravity. Examples of this include the rising clouds of cigarette smoke, or heat from the hood of a car that rises upwards. In forced convection, the fluid is forced to travel over the surface by a fan or pump or some other external source.

Heat Transfer and Radiation

Radiation (not to be confused with thermal radiation) refers to the transfer of heat through empty space. This form of heat transfer occurs without an intervening medium; radiation works even in and through a perfect vacuum. For instance, energy from the sun travels through the vacuum of space before the transfer of heat warms the Earth.

Heat transfer forms an integral part of education in relevant subjects, such as in the curriculum of chemical or mechanical engineering. Manufacturing and HVAC (heating, ventilating and air cooling) are examples of industries that rely heavily on thermodynamics and principles of heat transfer. Thermal science and thermal physics are higher fields of education that deal with heat transfer.

There are three types of heat transfer that can occur in any process.

1. Conduction
2. Convection
3. Radiation

- Conduction:- The phenomena of conduction occurs at molecular level. Whenever the medium between two end is stationary conduction occurs which we can normally see in solids. In liquids also conduction takes place first before convection.Molecules at higher temperature have high kinetic energy so they vibrate and collid with the adjacent molecules which are at lower temperature and thus transfers the heat. This is known as diffusion of energy. It is not necessary that conduction only occurs in solids.

- Convection:- Whenever the medium between two points has relative motion then it is convection. Convection is a surface phenomena. While heating, density difference occurs of the atoms or molecules at the part near to heating source and the part away from the heating source.
For example during boiling of water in a vessel you can see the bubbles moving up on the surface which is nothing but Convection due to density difference. During that heating of water it is observed experimentaly that the bottom most layer the molecules remains stationary so at that portion conduction occurs and that heat is transferd to the layers of molecule above it which is convection.

- Radiation :- Radiation is a wave phenomena. For conduction and Convection to occur a medium is necessary but in radiation even if the medium is not present i.e VACUUM heat can transfer (IN SPACE). Radiation occurs due to change in the electronic configuration of atoms or molecules. Radiation becomes prime when the source is at very high temperature or when there is not medium. For example between sun and earth the heat transfer occurs through radiation only.

Difference between steam and gas turbines

Steam turbines rotate in the currents caused by the hot water vapour. They form part of a closed water cycle in which water condenses and is then heated until it evaporates again. Steam turbines therefore do not come into contact with the fuel deployed and work at temperatures between 500 and 650 °C. Several steam turbines are often arranged in a row so that – configured for high, medium and low pressure – they are able to optimally convert the respective steam pressure into rotational movement.

Gas turbines on the other hand rotate directly in the hot combustion gases. With temperatures up to 1500 °C, these gases are much hotter than those in steam turbines. For this reason the blades are cooled with air that flows out of small openings and creates a "protective film" between the exhaust gases and the blades. Without cooling, the blade material would quickly wear out.

What is the difference between Steam Turbine and Gas Turbine?

• Steam turbine uses high pressure steam as the working fluid, while the gas turbine uses air or some other gas as the working fluid.

• Steam turbine is basically an expander delivering torque as the work output, while a gas turbine is a combined device of compressor, combustion chamber, and turbine executing a cyclic operation to deliver work as either torque or thrust.

• Steam turbine is only a component executing one step of the Rankine cycle, while gas turbine engine executes the whole Brayton cycle.

• Gas turbines can deliver either torque or thrust as the work output, while steam turbines almost all the time delivers torque as the work output.

• The efficiency of the gas turbines is much higher than the steam turbine due to higher operating temperatures of the gas turbines. (Gas turbines ~1500 0C and steam turbines ~550 0C)

• The space required for the gas turbines is much less than steam turbine operation, because steam turbine requires boilers and heat exchangers, which should be connected externally for heat addition.

• Gas turbines are more versatile, because many fuels can be used and working fluid, which has to be fed continuously, is readily available everywhere (air). Steam turbines, on the other hand, require large amounts of water for the operation and tend to cause problems in lower temperatures due to icing.

Heat Engine Classification

1. External Combustion Engine (EC Engine):

External combustion engines are those in which combustion takes place outside the machines. Heat produced during external combustion is used for inducing useful mechanical motion in the cylinder of the engine.

Steam Engine, Stirling Engine, Steam Turbine, Closed cycle gas turbine are the types of External Combustion Engines.

2. Internal Combustion Engine (IC Engine):

Internal combustion engines are those in which combustion takes place within the engine. Chemical energy of the fuel is converted to thermal energy, and thermal energy is converted to mechanical energy, which moves the piston up and down inside the cylinder. Power from the piston is transmitted to the crankshaft which is ultimately transmitted to the wheels via a transmission system. Modern automobiles use internal combustion engines for propulsion.

Gasoline Engine, Diesel Engine, Wankel Engine, Open Cycle Gas Turbine are the types of Internal Combustion Engines.

What Are Thermodynamic Processes?

Everyone is hot. Or rather, everyone has heat. Every atom and molecule in your body undergoes constant random motions that are impossible to predict. Those random motions are what we call heat energy.

Thermodynamics is the study of the movement of heat. If you touch a block of ice, it isn't always pleasant unless it's a really hot day. If you touch a hot pan out of the oven you'll burn yourself. Both of those things happen because of how fast heat is moving. The heat from the hot pan moves into your hand rapidly, and when touching an ice cube, you lose your own body heat fast. Heat transfers from hot places to cold places - or in other words, heat spreads out. Extreme heat or cold can damage our tissues, so it's a pretty important thing to understand. It's also how we've been able to build refrigerators and large insulated coolers to take to the beach.

These are examples of the many things we can do with heat if we understand how it moves within or between systems. A system is just a particular object or area we're looking at. Our system could be the inside of a thermos flask, or it could be the whole human body or just our skin, or the gas inside a piston. We choose the system we want to look at for convenience.

Then we can look at how heat moves in, out and within that system. We can look at how the system changes. A thermodynamic process is any process that involves heat energy moving within a system or between systems. In this lesson, we're going to look at the four types of thermodynamic processes.

The Four Types of Thermodynamic Processes

The four types of thermodynamic process are isobaric, isochoric, isothermal and adiabatic. Those terms are pretty hard to understand just from the names, so let's break them down one at a time.

Isobaric Process

An isobaric process is one where the pressure of the system (often a gas) stays constant. 'Iso' means the same, and 'baric' means pressure. Pressure is related to the amount of force that the molecules apply to the walls of the container. Imagine that you have a gas inside a movable piston and you heat that gas up. By heating the gas up you make the molecules move faster, which would normally increase the pressure. But at the same time the piston expands, increasing the volume and giving the molecules more room to move. Since the walls of the container are now bigger, the pressure can stay the same even though the molecules are moving faster. That makes it an isobaric process.

Isochoric Process

An isochoric process is one where the volume of the system stays constant. Again, 'iso' means the same and 'choric' means volume. Volume is the amount of space the material takes up. So this would be like heating a gas in a solid, non-expandable container. The molecules would move faster and the pressure would increase, but the size of the container stays the same.

Isothermal Process

An isothermal process is one where the temperature of the system stays constant. Thermal relates to heat, which is in turn related to temperature. Temperature is the average heat (movement) energy of the molecules in a substance.

An example of an isothermal process would be if we took a gas held behind a movable piston and compressed that piston: the volume has decreased, and the pressure behind the piston has increased, since the molecules have less space in which to move. When you compress a piston, you're using energy - you're doing work on the gas - so normally the molecules would gain energy and move faster, and the temperature would increase. So the only way for an isothermal process

to happen is if all that energy you put into compressing the gas comes out again, for example by putting a cold reservoir in contact with the piston.

Adiabatic process

In thermodynamics, an adiabatic process is one that occurs without transfer of heat or matter between a thermodynamic system and its surroundings. In an adiabatic process, energy is transferred to its surroundings only as work.[1][2] The adiabatic process provides a rigorous conceptual basis for the theory used to expound the first law of thermodynamics, and as such it is a key concept in thermodynamics.

Some chemical and physical processes occur so rapidly that they may be conveniently described by the term "adiabatic approximation", meaning that there is not enough time for the transfer of energy as heat to take place to or from the system.[3]

By way of example, the adiabatic flame temperature is an idealization that uses the "adiabatic approximation" so as to provide an upper limit calculation of temperatures produced by combustion of a fuel. The adiabatic flame temperature is the temperature that would be achieved by a flame if the process of combustion took place in the absence of heat loss to the surroundings.

Carnot cycle

The **Carnot cycle** is a theoretical thermodynamic cycle proposed by French physicist Sadi Carnot in 1824 and expanded upon by others in the 1830s and 1840s. It provides an upper limit on the efficiency that any classical thermodynamic engine can achieve during the conversion of heat into work, or conversely, the efficiency of a refrigeration system in creating a temperature difference by the application of work to the system. It is not an actual thermodynamic cycle but is a theoretical construct.

Every single thermodynamic system exists in a particular state. When a system is taken through a series of different states and finally returned to its initial state, a thermodynamic cycle is said to have occurred. In the process of going through this cycle, the system may perform work on its surroundings, for example by moving a piston, thereby acting as a heat engine. A system undergoing a Carnot cycle is called a Carnot heat engine, although such a "perfect" engine is only a theoretical construct and cannot be built in practice.[1] However, a microscopic Carnot heat engine has been designed and run.[2]

Essentially, there are two "heat reservoirs" forming part of the heat engine at temperatures T_h and T_c (hot and cold respectively). They have such large thermal capacity that their temperatures are practically unaffected by a single cycle. Since the cycle is theoretically reversible, there is no generation of entropy during the cycle; entropy is conserved. During the cycle, an arbitrary amount of entropy ΔS is extracted from the hot reservoir, and deposited in the cold reservoir. Since there is no volume change in either reservoir, they do no work, and during the cycle, an amount of energy $T_h \Delta S$ is extracted from the hot reservoir and a smaller amount of energy $T_c \Delta S$ is deposited in the cold reservoir. The difference in the two energies $(T_h - T_c)\Delta S$ is equal to the work done by the engine.

Carnot cycle when acting as a heat engine consists of the following steps:

1. Reversible isothermal expansion of the gas at the "hot" temperature, Th (isothermal heat addition or absorption). During this step (1 to 2 on Figure 1, A to B in Figure 2) the gas is allowed to expand, doing work on the surroundings by pushing up the piston (stage 1 figure, right). Although the pressure drops from points 1 to 2 (figure 1) the temperature of the gas does not change during the process because it is in thermal contact with the hot reservoir at Th, and thus the expansion is isothermal. Heat energy Q1 is absorbed from the high temperature reservoir resulting in an increase in the entropy of the gas by the amount

   $\Delta S_1 = Q_1 / T_h$ {\displaystyle \Delta S_{1}=Q_{1}/T_{h}}   .

2. Isentropic (reversible adiabatic) expansion of the gas (isentropic work output). For this step (2 to 3 on Figure 1, B to C in Figure 2) the gas in the engine is thermally insulated from both the hot and cold reservoirs. Thus they neither gain nor lose heat, an 'adiabatic' process. The gas continues to expand by reduction of pressure, doing work on the surroundings (raising the piston; stage 2 figure, right), and losing an amount of internal energy equal to the work done. The gas expansion without heat input causes it to cool to the "cold" temperature, Tc. The entropy remains unchanged.

3. Reversible isothermal compression of the gas at the "cold" temperature, Tc. (isothermal heat rejection) (3 to 4 on Figure 1, C to D on Figure 2) Now the gas in the engine is in thermal contact with the cold reservoir at temperature Tc. The surroundings do work on the gas, pushing the piston down (stage 3 figure, right), causing an amount of heat energy Q2 to leave the system to the low temperature reservoir and the entropy of the system to

   decrease by the amount $\Delta S_2 = Q_2 / T_c$ {\displaystyle \Delta S_{2}=Q_{2}/T_{c}}   . (This is the same amount of entropy absorbed in step 1, as can be seen from the Clausius inequality.)

4. **Isentropic compression of the gas (isentropic work input).** (4 to 1 on Figure 1, D to A on Figure 2) Once again the gas in the engine is thermally insulated from the hot and cold reservoirs, and the engine is assumed to be frictionless, hence reversible. During this step, the surroundings do work on the gas, pushing the piston down further (stage 4 figure, right), increasing its internal energy, compressing it, and causing its temperature to rise back to Th due solely to the work added to the system, but the entropy remains unchanged. At this point the gas is in the same state as at the start of step 1.

Reversed Carnot cycle

The Carnot heat-engine cycle described is a totally reversible cycle. That is, all the processes that comprise it can be reversed, in which case it becomes the Carnot refrigeration cycle. This time, the cycle remains exactly the same except that the directions of any heat and work interactions are reversed. Heat is absorbed from the low-temperature reservoir, heat is rejected to a high-temperature reservoir, and a work input is required to accomplish all this. The P-V diagram of the reversed Carnot cycle is the same as for the Carnot cycle except that the directions of the processes are reversed.[

Stress and Strain

Stress
The term stress (s) is used to express the loading in terms of force applied to a certain cross-sectional area of an object. From the perspective of loading, stress is the applied force or system of forces that tends to deform a body. From the perspective of what is happening within a material, stress is the internal distribution of forces within a body that balance and react to the loads applied to it. The stress distribution may or may not be uniform, depending on the nature of the loading condition. For example, a bar loaded in pure tension will essentially have a uniform tensile stress distribution. However, a bar loaded in bending will have a stress distribution that changes with distance perpendicular to the normal axis.
Simplifying assumptions are often used to represent stress as a vector quantity for many engineering calculations and for material property determination. The word *"vector"* typically refers to a quantity that has a "magnitude" and a "direction". For example, the stress in an axially loaded bar is simply equal to the applied force divided by the bar's cross-sectional area.
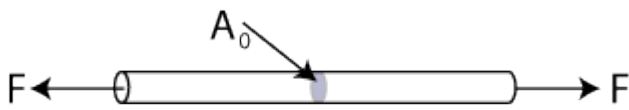
$$\text{Stress, } \sigma = \frac{\text{Force}}{\text{Cross-Sectional Area}} = \frac{F}{A_0}$$

Strain
Strain is the response of a system to an applied stress. When a material is loaded with a force, it produces a stress, which then causes a material to deform. Engineering strain is defined as the amount of deformation in the direction of the applied force divided by the initial length of the material. This results in a unitless number, although it is often left in the unsimplified form, such as inches per inch or meters per meter. For example, the strain in a bar that is being stretched in tension is the amount of elongation or change in length divided by its original length. As in the case of stress, the strain distribution may or may not be uniform in a complex structural element, depending on the nature of the loading condition.

$$\text{Strain} = \frac{\text{Elongation}}{\text{Orininal Length}} = \frac{\Delta L}{L_0}$$

If the stress is small, the material may only strain a small amount and the material will return to its original size after the stress is released. This is called elastic deformation, because like elastic it returns to its unstressed state. Elastic deformation only occurs in a material when stresses are lower than a critical stress called the yield strength. If a material is loaded beyond it elastic limit, the material will remain in a deformed condition after the load is removed. This is called plastic deformation.

Stress Concentration
When an axial load is applied to a piece of material with a uniform cross-section, the norm al stress will be uniformly distributed over the cross-section. However, if a hole is drilled in the material, the stress distribution will no longer be uniform. Since the material that has been removed from the hole is no longer available to carry any load, the load must be redistributed over the remaining material. It is not redistributed evenly over the entire remaining cross-sectional area but instead will be redistributed in an uneven pattern that is highest at the edges of the hole as shown in the image. This phenomenon is known as stress concentration.

Young's Modulus - Modulus of Elasticity (or Tensile Modulus) - Hooke's Law

Most metals deforms proportional to imposed load over a range of loads. Stress is proportional to load and strain is proportional to deformation as expressed with **Hooke's Law.**

E = stress / strain

Bulk Modulus Elasticity

The Bulk Modulus Elasticity - or Volume Modulus - is a measure of the substance's resistance to uniform compression. Bulk Modulus of Elasticity is the ratio of stress to change in volume of a material subjected to axial loading.

The Poisson's Ratio express

- the relative contraction strain (or transverse strain) normal to the applied load - to the relative extension strain (or axial strain) in the direction of the applied load

Shear Stress

Stress parallel to a plane is usually denoted as "shear stress" .

Shear Modulus of Elasticity - or Modulus of Rigidity

G = stress / strain

Physical Properties Of Metals

Below are the properties of metals:

Physical State: Metals are solids at room temperature with the exception of mercury and gallium, which are liquids at room temperature.

Lustre: Metals have the quality of reflecting light from its surface and can be polished e.g., gold, silver and copper.

Malleability: Metals have the ability to withstand hammering and can be made into thin sheets known as foils.

Ductility: Metals can be drawn into wires. 100 gm of silver can be drawn into a thin wire about 200 meters long.

Hardness: All metals are hard except sodium and potassium, which are soft and can be cut with a knife.

Mechanical properties

- Brittleness: Ability of a material to break or shatter without significant deformation when under stress; opposite of plasticity,examples:glass,concrete,cast iron,ceramics etc.
- Bulk modulus: Ratio of pressure to volumetric compression (GPa) or ratio of the infinitesimal pressure increase to the resulting relative decrease of the volume. brass has highest bulk modulus of 116 GPa.
- Coefficient of restitution:the ratio of the final to initial relative velocity between two objects after they collide. Range : 0-1, 1 for perfectly elastic collision.
- Compressive strength: Maximum stress a material can withstand before compressive failure (MPa)
- Creep: The slow and gradual deformation of an object with respect to time
- Ductility: Ability of a material to deform under tensile load (% elongation)
- Durability: Ability to withstand wear, pressure, or damage; hard-wearing.
- Elasticity: Ability of a body to resist a distorting influence or stress and to return to its original size and shape when the stress is removed
- Fatigue limit: Maximum stress a material can withstand under repeated loading (MPa)
- Flexibility: Ability of an object to bend or deform in response to an applied force; pliability; complementary to stiffness
- Flexural modulus
- Flexural strength : The stresses in a material just before it yields.
- Fracture toughness: Ability of a material containing a crack to resist fracture (J/m^2)
- Hardness: Ability to withstand surface indentation and scratching (e.g. Brinnell hardness number)
- Plasticity: Ability of a material to undergo irreversible or permanent deformations without breaking or rupturing; opposite of brittleness

- Poisson's ratio: Ratio of lateral strain to axial strain (no units)
- Resilience: Ability of a material to absorb energy when it is deformed elastically (MPa); combination of strength and elasticity
- Shear modulus: Ratio of shear stress to shear strain (MPa)
- Shear strength: Maximum shear stress a material can withstand
- Size
- Slip: A tendency of a material's particles to undergo plastic deformation due to a dislocation motion within the material. Common in Crystals.
- Specific modulus: Modulus per unit volume (MPa/m^3)
- Specific strength: Strength per unit density (Nm/kg)
- Specific weight: Weight per unit volume (N/m^3)
- Stiffness: Ability of an object to resist deformation in response to an applied force; rigidity; complementary to flexibility
- Surface roughness:the deviations in the direction of the normal vector of a real surface from its ideal form.
- Tensile strength: Maximum tensile stress of a material can withstand before failure (MPa)
- Toughness: Ability of a material to absorb energy (or withstand shock) and plastically deform without fracturing (or rupturing); a material's resistance to fracture when stressed; combination of strength and plasticity
- Viscosity: A fluid's resistance to gradual deformation by tensile or shear stress; thickness
- Yield strength: The stress at which a material starts to yield plastically (MPa)
- Young's modulus: Ratio of linear stress to linear strain (MPa)
- Strength of materials (relation of various strengths)

Properties of Fluids

Properties of fluids determine how fluids can be used in engineering and technology. They also determine the behaviour of fluids in fluid mechanics. The following are some of the important basic properties of fluids:

1. Density
2. Viscosity
3. Temperature
4. Pressure
5. Specific Volume
6. Specific Weight
7. Specific Gravity

Cavitation

If the speed through the valve is increases enough, the pressure in the fluid drops to a level where the fluid may start to boil, bubble or flash. And when the pressure recovers sufficiently the bubbles will collapse upon themselves. This collapse causes cavitation. Cavitation may be noisy but is

usually of low intensity and low frequency. This situation is extremely destructive and may wear out the trim and body parts of a valve in short time.
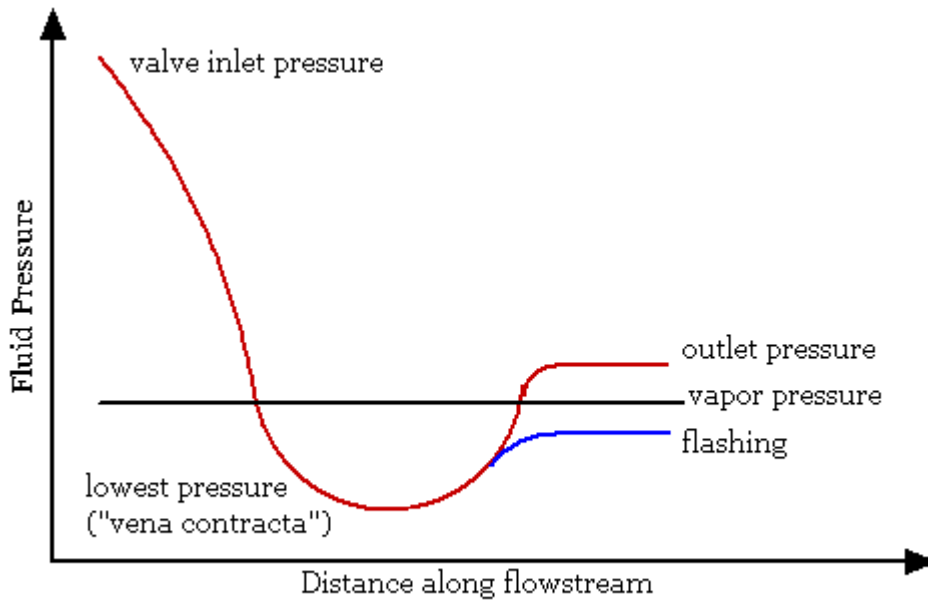
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Flashing is a vaporizing process similar to cavitation. However, flashing differs from cavitation in that the vapor phase persists and continues downstream because the downstream pressure remains at or below.

Vapor pressure

Vapor pressure or equilibrium vapor pressure is defined as the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases (solid or liquid) at a given temperature in a closed system. The equilibrium vapor pressure is an indication of a liquid's evaporation rate. It relates to the tendency of particles to escape from the liquid (or a solid). A substance with a high vapor pressure at normal temperatures is often referred to as volatile. The pressure exhibited by vapor present above a liquid surface is known as vapor pressure. As the temperature of a liquid increases, the kinetic energy of its molecules also increases. As the kinetic energy of the molecules increases, the number of molecules transitioning into a vapor also increases, thereby increasing the vapor pressure.

Boiling point

The boiling point of a substance is the temperature at which the vapor pressure of the liquid equals the pressure surrounding the liquid[1][2] and the liquid changes into a vapor.

The boiling point of a liquid varies depending upon the surrounding environmental pressure. A liquid in a partial vacuum has a lower boiling point than when that liquid is at atmospheric pressure. A liquid at high pressure has a higher boiling point than when that liquid is at atmospheric pressure. For example, water boils at 100 °C (212 °F) at sea level, but at 93.4 °C

(200.1 °F) at 2,000 metres (6,600 ft) altitude. For a given pressure, different liquids will boil at different temperatures.

The normal boiling point (also called the atmospheric boiling point or the atmospheric pressure boiling point) of a liquid is the special case in which the vapor pressure of the liquid equals the defined atmospheric pressure at sea level, 1 atmosphere.[3][4] At that temperature, the vapor pressure of the liquid becomes sufficient to overcome atmospheric pressure and allow bubbles of vapor to form inside the bulk of the liquid. The standard boiling point has been defined by IUPAC since 1982 as the temperature at which boiling occurs under a pressure of 1 bar.[5]

The heat of vaporization is the energy required to transform a given quantity (a mol, kg, pound, etc.) of a substance from a liquid into a gas at a given pressure (often atmospheric pressure).

Liquids may change to a vapor at temperatures below their boiling points through the process of evaporation. Evaporation is a surface phenomenon in which molecules located near the liquid's edge, not contained by enough liquid pressure on that side, escape into the surroundings as vapor. On the other hand, boiling is a process in which molecules anywhere in the liquid escape, resulting in the formation of vapor bubbles within the liquid.

Flow coefficient, Cv for control valves

The flow coefficient of a device is a relative measure of its efficiency at allowing fluid flow. It describes the relationship between the pressure drop across an orifice, valve or other assembly and the corresponding flow rate.

In more practical terms, the flow coefficient Cv is the volume (in US gallons) of water at 60° F that will flow per minute through a valve with a pressure drop of 1 psi across the valve.

The use of the flow coefficient offers a standard method of comparing valve capacities and sizing valves for specific applications that is widely accepted by industry.

What is Control Valve Rangeability?
## Field Instrumentation Valves

Control Valve What is Valve Rangeability ?

Rangeability is the ratio of maximum controllable flow to minimum controllable flow

For the control valve selection rangeability is one of the important selection factor.

Minimum and Maximum Cv of Valves are calculated .If the ratio of Cv Maximum to Cv Minimum is within the rangeability of the selected control valve ,the valve should function properly
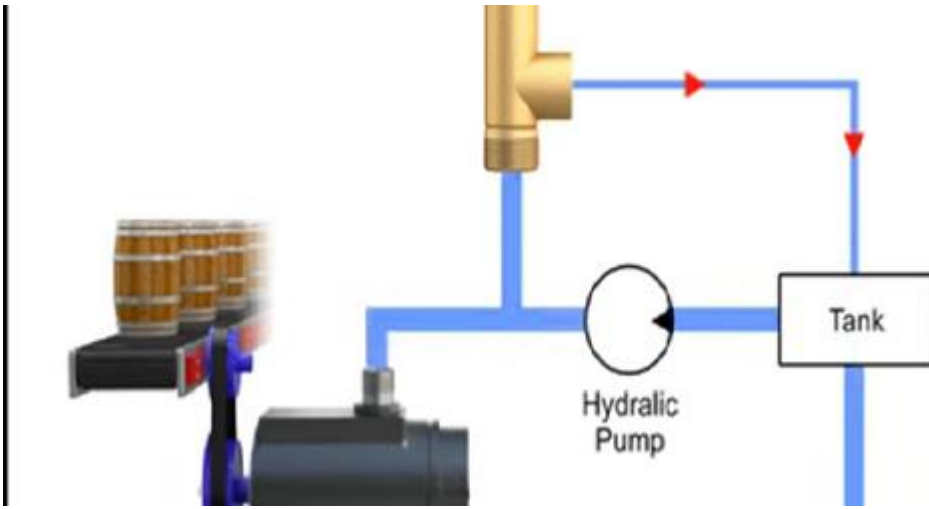
Pressure relief valves
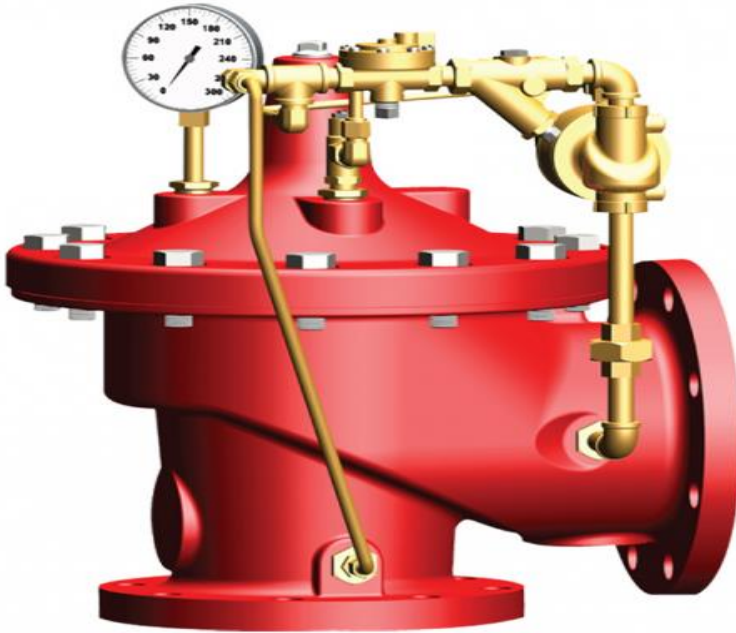
The pressure relief valve is an important type of safety valve. A pressure relief valve protects motors, pumps and actuators from becoming damaged from high pressure. When the pressure inside such equipment increases beyond a specified value, the excess pressure may result in a failure or damage called catastrophic failure occurs. To avoid such calamity, pressure relief devices are used at predetermined set pressures to protect the equipment by relieving the excess pressure.

Pressure Relief Valve
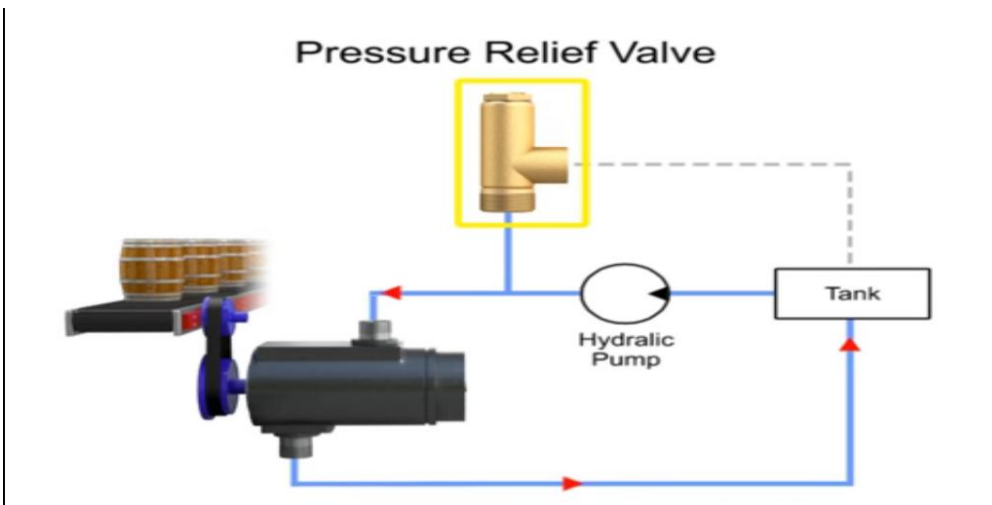
The valve remain closed for normal operation. And no water passes through the valve.

When the pressure in the loop exceeds the limit the valve opens, and the relief the excess pressure. Thus protects the expensive machinery. Without a pressure relief valve excess pressure directly exposed to machinery damages them.

Categories:

- Direct acting
- Pilot operated

Direct acting:

Direct Acting Relief Valve

Spring Force

Adjustment knob

System Hydraulic Pressure
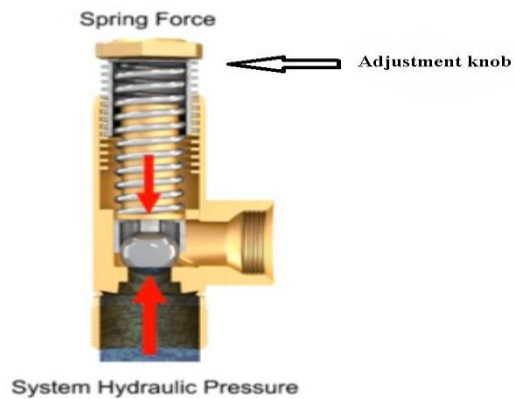
During normal pressure the valve held closed by a mechanical spring. The pressure exerted by the spring and the fluid will be the same, so the valve won't open. The spring tension can be adjusted by rotating the adjustment knob. Adjustment knob is adjusted to specified position for a cracking pressure, where cracking pressure is pressure when the valve starts to open.

Spring Force

Full Relief Valve Pressure
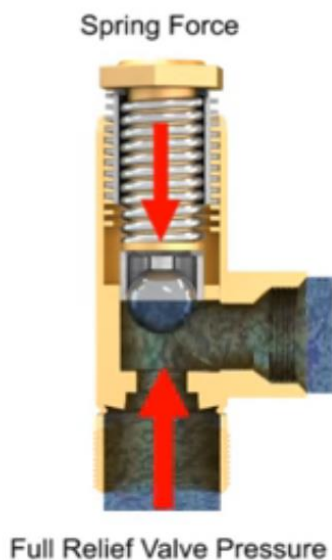
Beyond the cracking pressure the valve begins to open and the fluid starts to trickles through. the pressure at which the valve fully open is the full relief valve pressure. At this pressure valve is fully opened.

Pilot operated relief valve:

Pilot Spring

Pilot Poppet

Main Spring

Main Poppet

Adjustment Knob

Tank Return

Pump Line Pressure
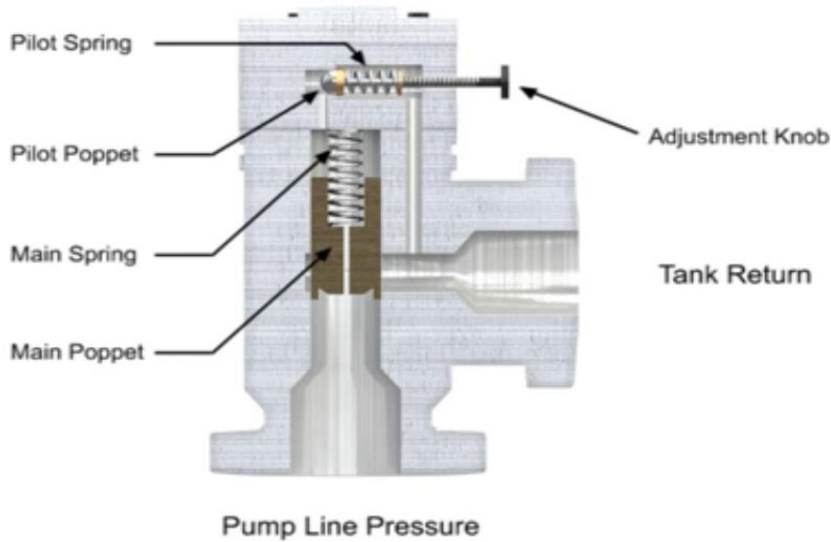
The difference between a pilot-operated safety relief valve and a direct acting pressure relief valve is that the pilot-operated valve uses process pressure to keep the valve closed instead of a spring. The first stage consist of main poppet and main spring. Now the second stage consist of pilot poppet, pilot spring, adjustment knob.

Pilot Spring

Pilot Poppet

Main Spring

Main Poppet

Adjustment Knob

Tank Return
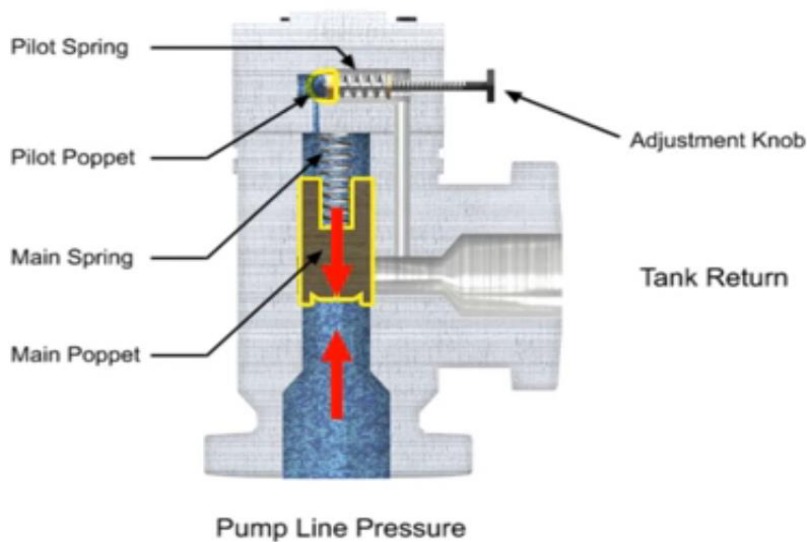
Pump Line Pressure

Until the pump line pressure exceeds the relieving pressure set on the control knob, the pilot poppet remain closed. And the main poppet.
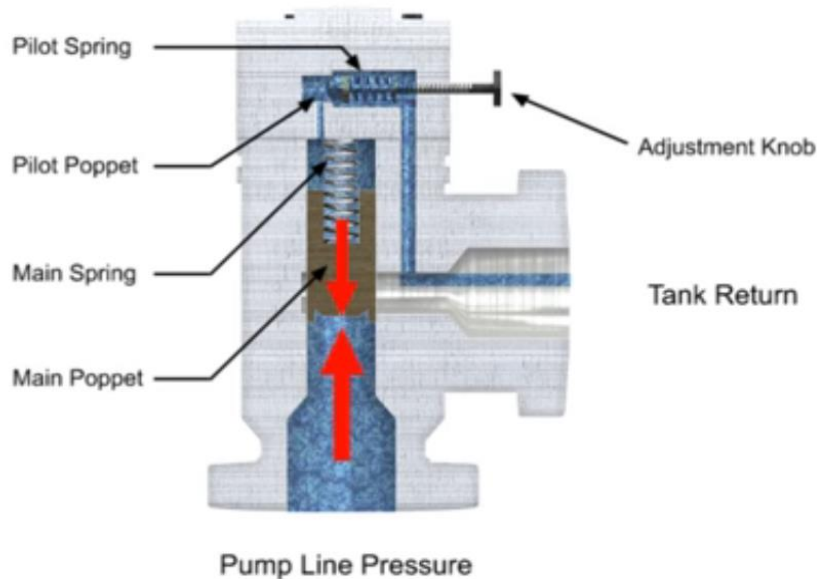
Pump Line Pressure

.
when the pump line pressure increase the pilot moves to open position. And the water flows out to the tank,
Know there is a pressure drop across the main poppet.
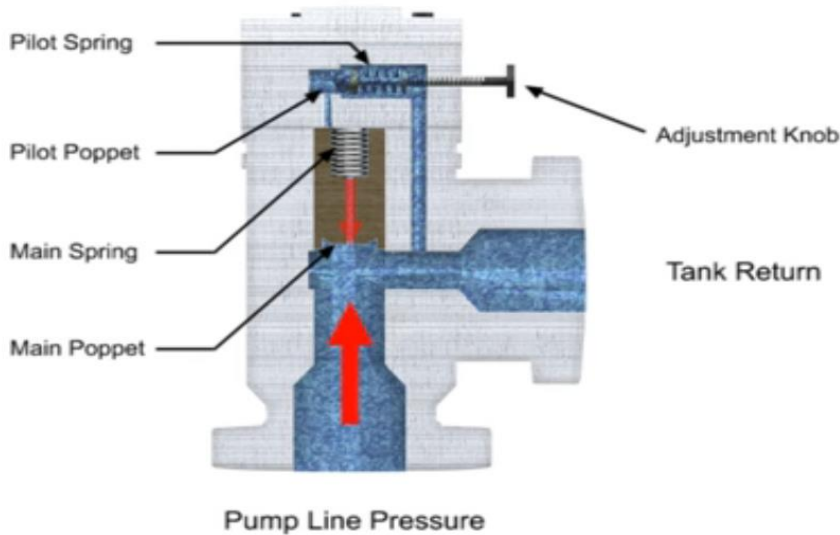
Pump Line Pressure

Due to the pressure drop across the main poppet, the main moves up, so the valve opens.
Same thing happens when the pump line pressure drops the pressure difference cause the main poppet close.

PURPOSE AND FUNCTION OF SAFETY VALVES

The primary purpose of a safety valve is the protection of life, property and environment. A safety valve is designed to open and relieve excess pressure from vessels or equipment and to reclose and prevent the further release of fluid after normal conditions have been restored.

A safety valve is a safety device and in many cases the last line of defence. It is important to ensure that the safety valve is capable to operate at all times and under all circumstances. A safety valve is not a process valve or pressure regulator and should not be misused as such. It should have to operate for one purpose only: overpressure protection.

REASONS FOR EXCESS PRESSURE IN A VESSEL

There are a number of reasons why the pressure in a vessel or system can exceed a predetermined limit. API Standard 521/ISO 23251 Sect. 4 provides a detailed guideline about causes of overpressure. The most common are:

- Blocked discharge
- Exposure to external fire, often referred to as "Fire Case"
- Thermal expansion
- Chemical reaction
- Heat exchanger tube rupture
- Cooling system failure

Each of the above listed events may occur individually and separately from the other. They may also take place simultaneously. Each cause of overpressure also will create a different mass or volume flow to be discharged, e.g. small mass flow for thermal expansion and large mass flow in case of a chemical reaction. It is the user's responsibility to determine a worst case scenario for the sizing and selection of a suitable pressure relief device.

SAFETY RELIEF VALVES WORKING PRINCIPLE

Gases and steams can be compressed, when gas reaches the disk in a valve it compresses and builds up before escaping through the valve. This compression can cause system pressure to build up rapidly. A liquid type **relief valve** doesn't open fast enough to relief gas or steam pressure. A gas system requires a valve that can open wide open under excess pressure or **pressure safety valve**.

Even though safety valve relief pressure more quickly than relief valve, the design and component of both valves are very similar. A direct acting safety valve consists of a casing, inlet, outlet, disc, seat, spindle, cap and lifting lever on some valves.

The safety valve assembly is protected by the casing which is threaded or flanged for connection to the system. A cap covers the top of the assembly and reduces the change of tempering with the valve setting. The disk is held in place until the system pressure increases to the point when the disc pop-off the seat. The spindle guides the up and down motion of the disc. The **adjusting screw** is used to adjust the valve set point. If the spring tension changes over period of time, certified personnel would reset the adjusting screw.

The popping open of the safety valve is due to the design of the disk. There is a main surface of the disk which is always in contact with system pressure and a lip which is not exposed to system pressure. At the set point the disk will lift off the seat but what makes this valve different is that the lip is become expose to the system pressure creating a larger surface for the system pressure to press against. This large area makes a larger lifting force and causes the valve to pop open. When the pressure drops to a safe level the same operation happened in reverse. Because of the high velocity of the escaping gas, the valve must close quickly and completely otherwise the high velocity can damage the surfaces of the valve opening.

Damage is also prevented by a key feature of safety valve operation known as the Huddling Chamber. This chamber provides a small cushion that keeps the disk from slamming in to the seat and damaging the valve.

The pressure of which the valve opens all the way is called the popping pressure. The opposite rapid closure of the valve is called positive seating pressure. The different between the popping

pressure and the positive seating is called **blowdown**. For example if pooping pressure is 200 psi and the positive seating pressure is 190 psi, the blowdown is 10 psi.

Determine Constant Demand
In some applications, the required relief capacity can be reduced by subtracting any load that is always on the system. This procedure should be approached with caution because it may be difficult to
predict the worst-case scenario for downstream equipment failures. It may also be important to compare the chances of making a mistake in predicting the level of continuous flow consumption with the potential negative aspects of an error. Because of the hazards involved, relief valves are often sized assuming no
continuous flow to downstream equipment.

Selecting Relief Valves

Required Information

We have already reviewed the variables required to calculate the regulator's wide-open flow rate. In addition, we need to know the the maximum allowable pressure of the system, and the size of the piping. Finally, if a vent stack will be required, any additional build-up due to vent stack resistance should be considered.

Regulator Lockup Pressure

A relief valve setpoint is adjusted to a level higher than the regulator's lockup pressure. If the relief valve setpoint overlaps lockup pressure of the regulator, the relief valve may open while the regulator is still attempting to control the system pressure.

Identify Appropriate Relief Valves

Once the size, relief pressure, and flow capacity are determined, we can identify a number of potentially suitable relief valves.Final selection is usually a matter of compromise. Relief capacities, build-up levels, sensitivity, throttling capabilities, cost of installation and maintenance, space requirements, initial purchase price, and other attributes are all considered when choosing any relief valve.

Set Pressure and Overpressure Relationships for Sizing
Set pressure and overpressure requirements vary with the installation and application of the pressure relief valve(s). The installation may require one or more pressure relief valves per ASME Section VIII and API RP 520. The application will require the pressure relief valve(s) to provide overpressure protection caused by non-fire or fire-related events.

In all cases the overpressure of the pressure relief valve will be the difference between the accumulation of the system and the pressure relief valve's set pressure. In determining the required pressure relief valve orifice area, the flowing pressure value (P1) will be set equal to the system accumulation value.

Single Valve Installations

Used when only one pressure relief valve is required for system overpressure protection.

1) If the overpressure is not due to a fire exposure event:

a) The set pressure may be equal to or less than the MAWP of the protected system.

b) The accumulation of the system must not exceed the larger of 3 psi or 10% above the MAWP (see Table 1.)

2) If the overpressure is due to a fire exposure event on a vessel:

a) The set pressure may be equal to or less than the MAWP of the protected system.

b) The accumulation of the system must not exceed 21% above MAWP

Multiple Valve Installations

Applies when more than one pressure relief valve is required for system overpressure protection.

1) If the overpressure is not due to a fire exposure event:

a) The set pressure of at least one valve must be equal to or less than the MAWP of the protected system. The set pressure of any of the remaining valve(s) must not exceed 1.05 times the MAWP.

b) The accumulation of the system must not exceed the larger of 4 psi or 16% above the MAWP (see Table 3.)

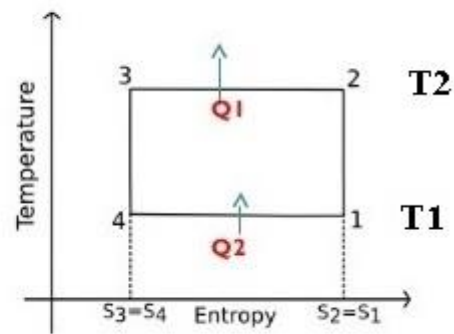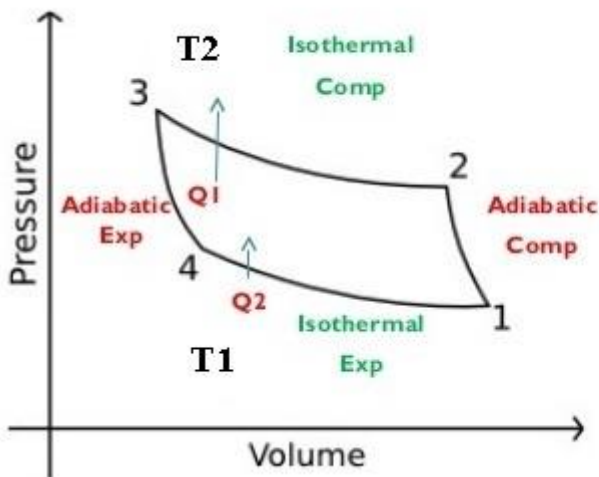2) If the overpressure is due to a fire exposure event on a vessel:

a) The set pressure of at least one valve must be equal to or less than the MAWP of the protected system. The set pressure of any of the remaining valve(s) must not exceed 1.10 times the MAWP.

b) The accumulation of the system must not exceed 21% above MAWP.

REVERSE CARNOT CYCLE

- Reversing the Carnot cycle does reverse the directions of heat and work interactions. A refrigerator or heat pump that operates on the reversed Carnot cycle is called a Carnot refrigerator or a Carnot heat pump.

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Pumps

Rotodynamic pumps

- Low head
  - Axial pump (propeller)
- Medium head
  - Centrifugal Pump
  - Mixed flow type
- High head
  - Centrifugal Pump
  - Radial type

Positive displacement pumps

- Reciprocating (very high pressure pumps)
  - Piston pump
  - Plunger pump
  - Diaphragm pump
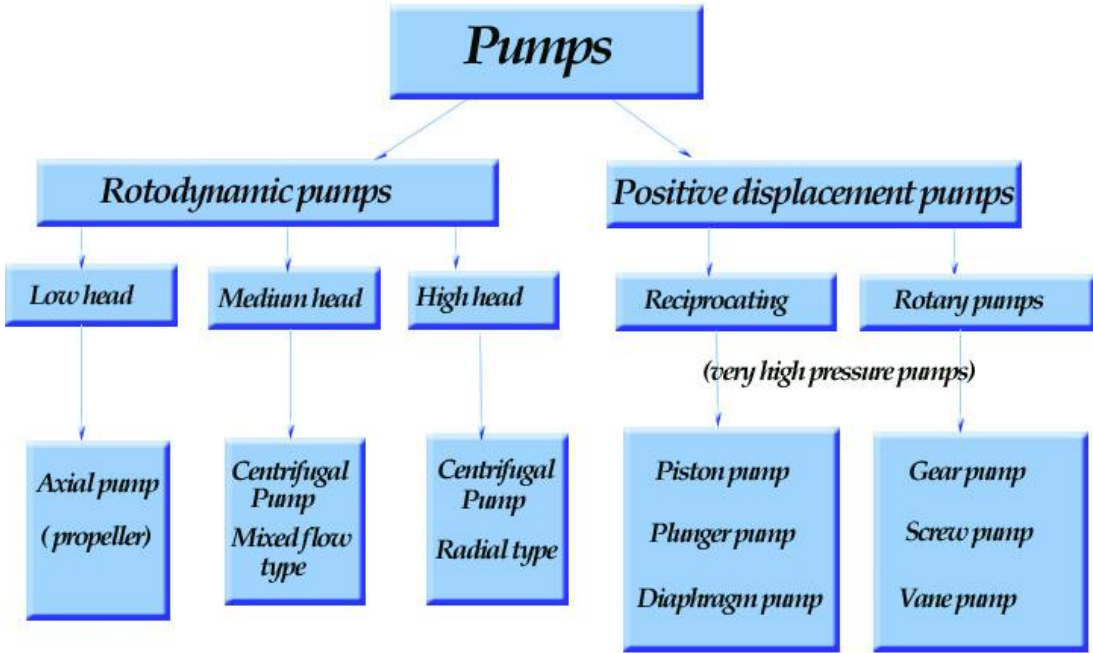- Rotary pumps
  - Gear pump
  - Screw pump
  - Vane pump
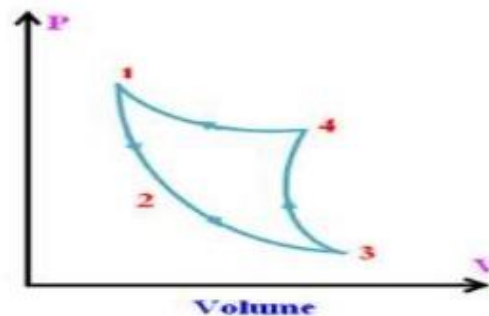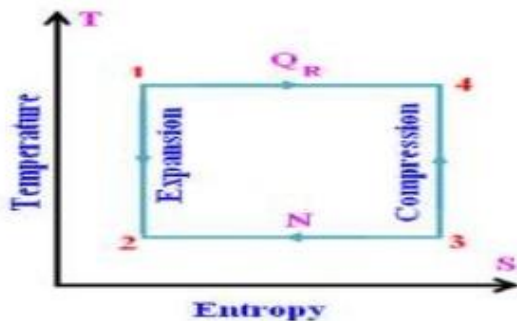
MOST COMMON PUMPS
Please Click on the pump type of interest, for the animation.

GEAR

VANE

HOSE

MULTIPLEX

CENTRIFUGAL

Air Driven INTENSIFIER

AODeD
AODD

LOBE

MULTI-LAYER DIAPHRAGM HEAD METERING

PROGRESSIVE CAVITY FOR SLUDGE & SLURRY

INJECTION, / PACKED PLUNGER

"Wobble Plate" —or— "Swash Plate" —or— "Slipper Pad" —or—

Axial Piston Pumps
Compact, high pressure, high horse power.

Das Pump Haus Inc.

RADIAL PISTON

WITH SUCTION TURBO
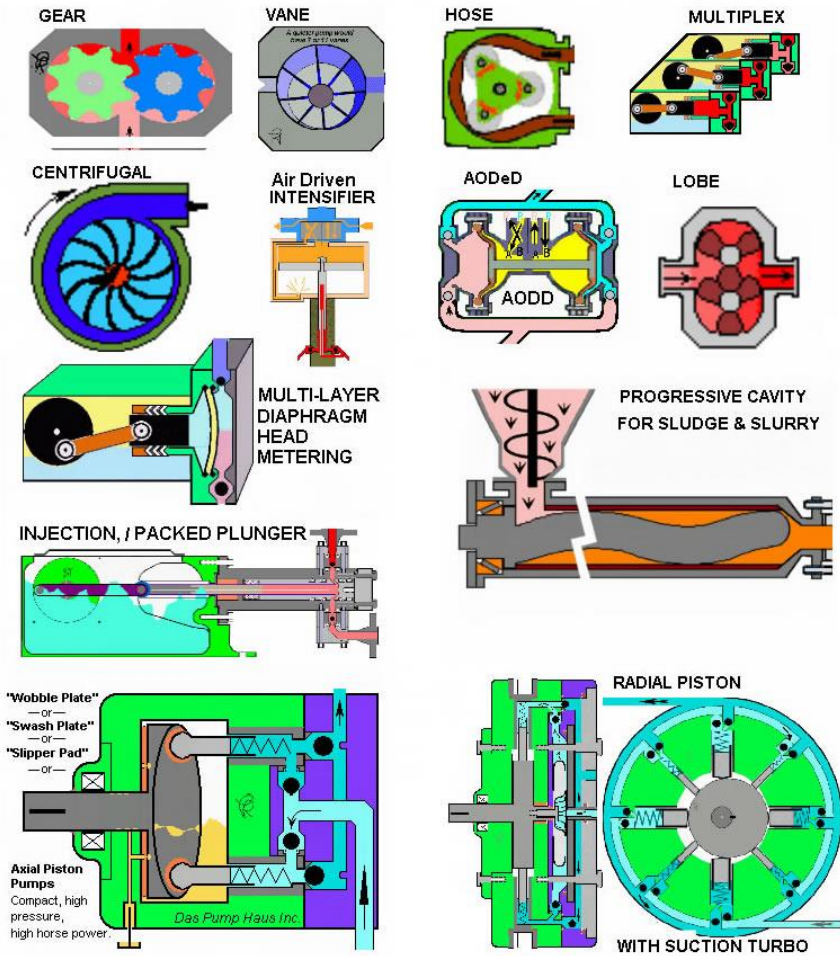
API Standards for Pressure Relieving Systems

| API Standard	Title	Description
API-520 Part I	Sizing, Selection, and Installation of Pressure Relieving Devices in Refineries—Part I, Sizing and Selection	Guide for sizing and selection of pressure relief devices used in petroleum related industries for equipments with maximum allowable working pressure of 15 psig greater. The document is intended for protection of unfired pressure vessels and equipments against overpressure from operation or fire. Pressure relief valves or rupture disks may be used independently or in combination with each other to provide the required protection against excessive pressure accumulation{adinserter 1}
API-520 Part II	Sizing, Selection, and Installation of Pressure Relieving Devices in Refineries—Part II, Installation	Guide for installation of pressure relief devices used in petroleum related industries for equipments with maximum allowable working pressure of 15 psig greater.
API-521	Guide for Pressure relieving and Depressuring Systems Petroleum petrochemical and natural gas industries—Pressure relieving and depressuring systems	This API standard specifies requirements and gives guidelines for determining overpressure causes, relieving rates for pressure relieving and vapor depressurizing systems in petroleum related industries. The standard also discusses selection and design of disposal systems, including such component parts as piping, vessels, flares, and vent stacks.{adinserter 1}
API-526	Flanged Steel Pressure relief Valves	The standard covers specifications for flanged steel pressure relief valves (PRVs) by presenting basic requirements such as orifice designation and area, valve size, pressure rating, materials etc. for direct spring-loaded pressure relief valves and pilot-operated pressure relief valves.

API-527	Seat Tightness of Pressure Relief Valves	Describes methods of determining the seat tightness of metal- and soft-seated pressure relief valves (PRVs), including those of conventional, bellows, and pilot-operated designs.
API-576	Inspection of Pressure-relieving Devices	Describes the inspection and repair practices for automatic pressure relieving devices commonly used in the oil and petrochemical industries. This API standard covers pressure relief valves, pilot-operated pressure relief valves, rupture disks, and weight-loaded pressure-vacuum vents, with regards to inspection and repair.
API-2000	Venting Atmospheric and Low-pressure Storage Tanks Petroleum, petrochemical and natural gas industries—Venting of atmospheric and low-pressure storage tanks	Guide for normal and emergency vapor venting requirements for above ground petroleum and petroleum product storage tanks, above ground and underground refrigerated storage tanks. The tanks discussed in the document are designed for low pressures ranging from full vacuum through 15 psig. This API standard discusses causes of overpressure and vacuum, venting requirements, means of venting, selection, and installation of venting devices and testing and marking of relief devices etc for storage tanks.{adinserter 1}

CLASSIFICATION :
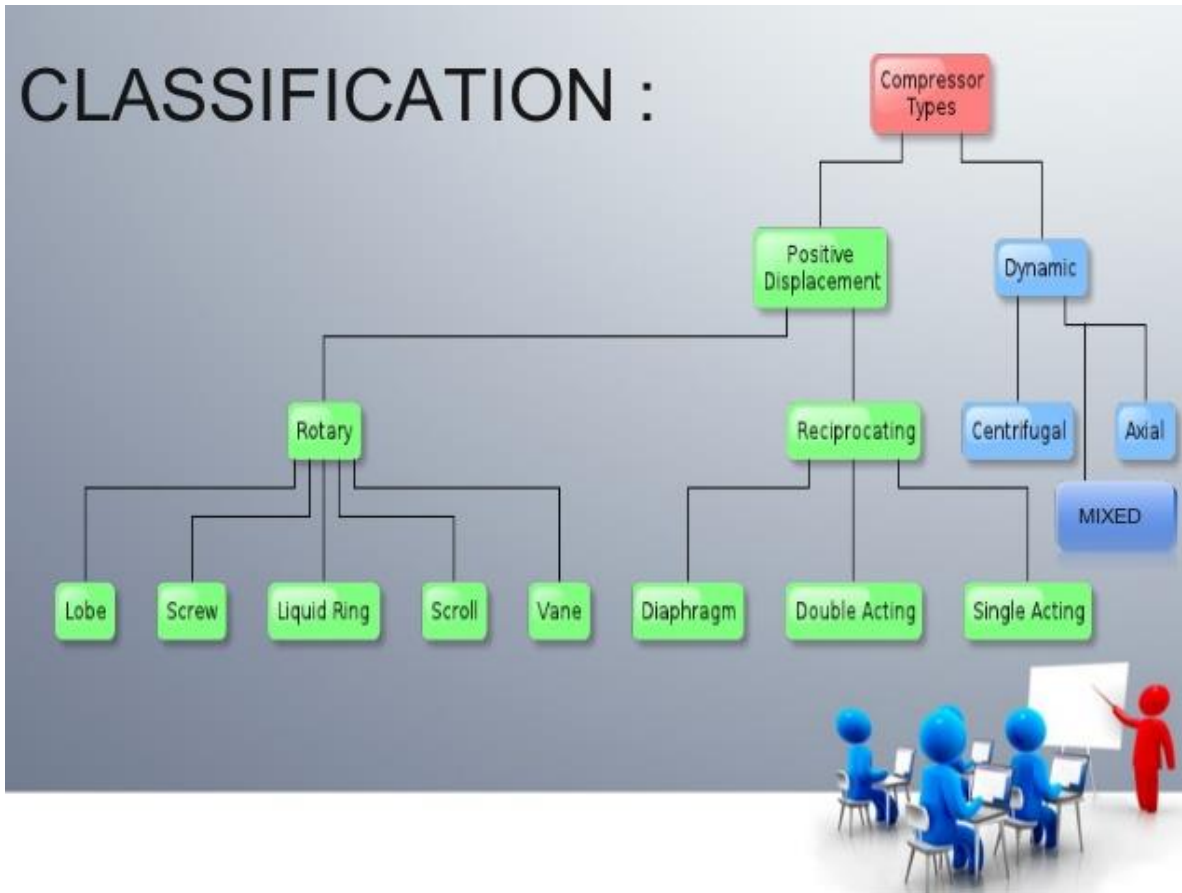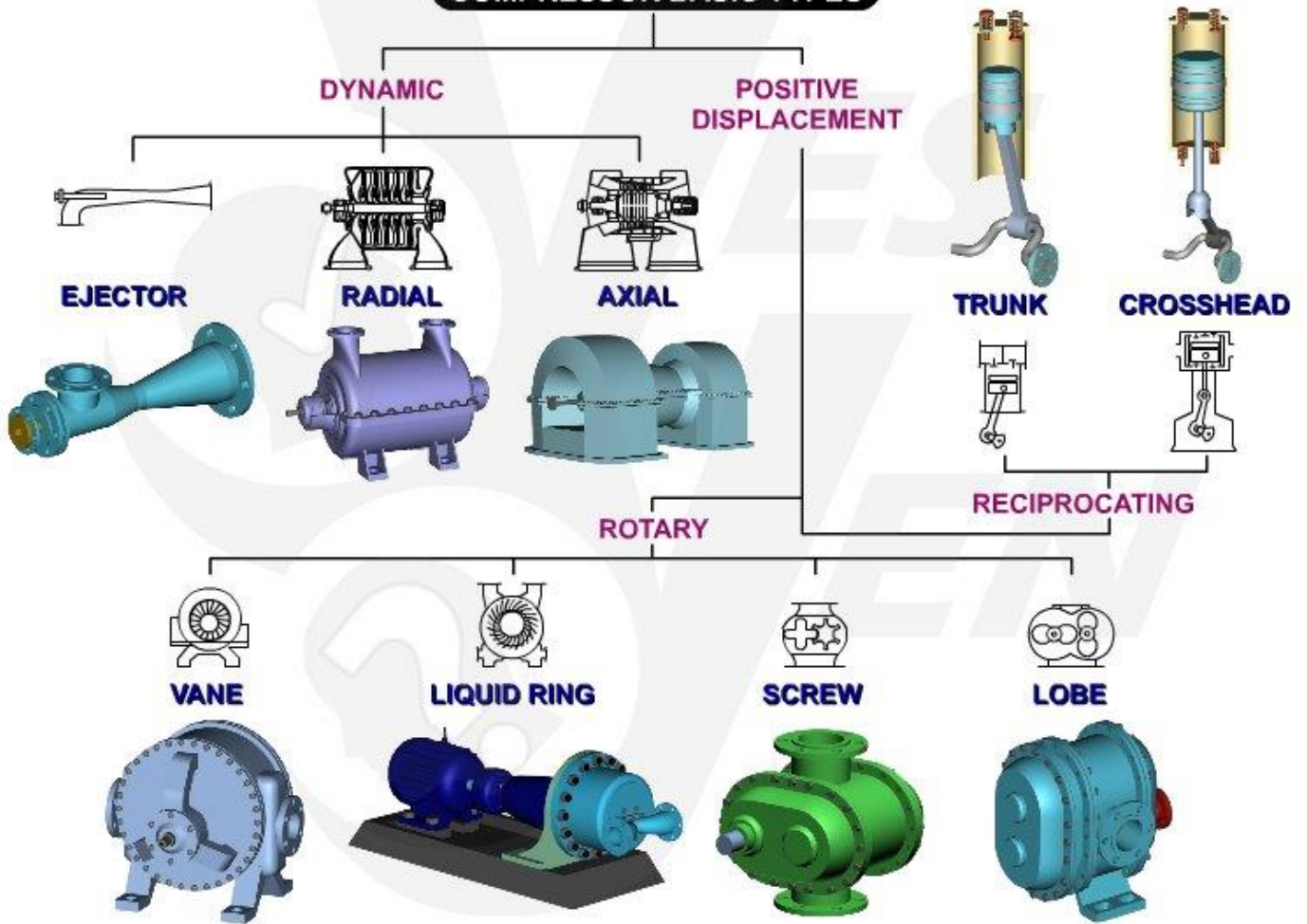
Rupture discs – an introduction

Why rupture discs

Rupture discs are, next to safety valves, the most commonly used pressure protection devices in industrial plants. They protect vessels and pipelines from deformation and other damage. The main objective is to optimally protect and, at the same time, minimise the downtime of the system.

What is a rupture disc

Rupture discs are safety devices with a defined breaking point, which respond to a specific pressure and are used for pressure relief in the most diverse range of applications. They are used to protect against overpressure or vacuum within a process, for the protection of man, environment and machine. Originally a very simple solution, rupture discs have evolved enormously in response to growing industry requirements such as alternating pressures or higher process temperatures, and the increasing technologisation of processes in recent years. The biggest advantage over electronic, pneumatic, or spring loaded safety systems is the failsafe performance of rupture discs - this makes them the most economical and most important safety device in industrial enterprises. High reliability is important to prevent unnecessary downtime of the system. However, how failsafe a rupture disc is significantly depends on the workmanship and the material used.

Design of rupture discs

Rupture discs for pressure relief are round or square, consist of one or more layers, and are either flat or domed.

Many rupture discs are equipped with breaking points which are created for example, by means of lasers. These can be simple cuts or even special geometries. This part of the rupture discs is known as the rupture element.

Different applications require different types of rupture discs. They are made of metals or plastics, from one or more layers, and they can be domed or flat. Domed rupture discs either have the dome towards the process (reverse-acting rupture disc), or away from the process (forward-acting rupture discs). Within these different varieties, there is a broad range of possible combinations.

For example, plastic film is sandwiched between metal layers for triple section rupture discs, in order to reach even the lowest burst pressures. The materials used range from various stainless steels to higher quality materials such as Inconel, Hastelloy, or Tantalum, and all the way up to coatings or plastic liners such as PTFE or FEP.

Rupture discs are either installed directly between flanges, or inserted into a corresponding rupture disc holder, which is then mounted between flanges. In some cases the rupture disc is already soldered or welded into the holder by the manufacturer. These holders are then fitted with the necessary connections, e.g. thread (NPT, G or customer-specific thread, connection systems (e.g. VCR) or various flanges (ISO-K, KF, ISO-F, CF)).

A large number of rupture discs and other safety devices are installed in industrial plants. A broad range of signalling options are available, to immediately receive information about the triggering (opening) of a rupture disc. The easiest way to achieve this is with a tripping wire which is fixed on the rupture disc, and is connected to the process control system. With the opening of the bursting disc, the wire breaks, the circuit is interrupted and the triggering of the rupture disc is communicated to the process control system. If there are particularly high demands for leak-tightness, non-invasive signalling methods (e.g. magnetic proximity sensor NIMU) are used.

Type classification of rupture discs

Reverse-acting rupture disc
The dome of the rupture disc faces the process and enables very high operating pressures (see also: key technical information on rupture discs) and a very high operating pressure ratio.

Forward-acting rupture discs
The dome of the rupture discs is faced away from the process.

Compact rupture discs
These are usually very small nominal pipe size of reverse-acting or forward-acting rupture discs which are often adhesively bonded or soldered to the housing / holder.

RUPTURE DISCS AND SAFETY VALVES

Rupture discs and safety valves can be combined in two different configurations: The rupture disc can be installed below the safety valve or the two pressure relief systems installed prallel. If the systems are installed next to each other, **the response pressure of the rupture disc is higher than that of the safety valve.** If the rise in pressure is so large and rapid that the safety valve cannot respond sufficiently quickly or if it fails to open, the **rupture disc serves as a reliable backup system to relieve the pressure.** If the rupture disc is installed below the safety valve it can perform a number of roles:

Improved leak-tightness

Even if your process does not involve toxic or very expensive media – safety equipment should still ideally be able to operate leak-free over long periods. Safety valves tend to leak more after being triggered for the first time. However, a REMBE® rupture disc positioned upstream of the safety valve ensures a perfect, leak-tight seal and saves you money. After all, it is cheaper to replace a rupture disc than a safety valve.

A relief valve secures the space between the rupture disc and the safety valve.

Protection against "challenging" media

Every operator who has ever been in this position knows the problem: The functionality and reliability of some safety equipment is affected to a greater or lesser degree by corrosive, adhesive, polymerising or viscous media.

This also applies to safety valves. If the valve seat is sticky, it is no longer possible to guarantee the defined response pressure. This poses a risk even before the first time the safety valve is triggered. Cleaning and inspections are therefore essential toguarantee that – in the case of an emergency – the safety valve responds at the specified pressure. A REMBE® rupture disc installed upstream protects the safety valve against caking and adhesions. Reverse acting rupture discs like KUB® have a smooth metal surface on the side facing the process, which prevents the build of deposits. Breaking points are isolated from the process. This ensures that the specified response pressure is maintained at all times and eliminates the possibility of a late response.

Special safety valves and KUB® Clean are used in hygienic applications.

In liquids, gases and two-phase media, a REMBE® rupture disc upstream from your safety valve simply saves you money:

- Improved leak-tightness for lower loss of media and long-term compliance with regulations and legal requirements.
- You can use safety valves made from lower cost materials even with corrosive, adhesive or polymerising media.
- Additional savings through in-situ tests.

The combination of a rupture disc prior to a safety valve is becoming more and more important – and rightly so if you ask me. Our rupture discs provide protection for safety valves while at the same time saving money on maintenance and re-engineering. And of course no operator wants to waste money, do they?

In-situ testing of safety valves

Normally, safety valves have to be removed in order to test whether they are functioning correctly. This is time-consuming and expensive. However, in combination with REMBE® rupture discs, you can test your safety valves without moving them anywhere. To do this, the space between the rupture disc and the valve stroke is pressurised.

As KUB® has a back pressure resistance of 135 %, the rupture disc remains undamaged while the safety valve is being inspected. If in-house regulations nonetheless require the safety valve to be removed for inspection, the rupture disc can be left in position in a separate flange connection in order to close the opening while this work is being performed.
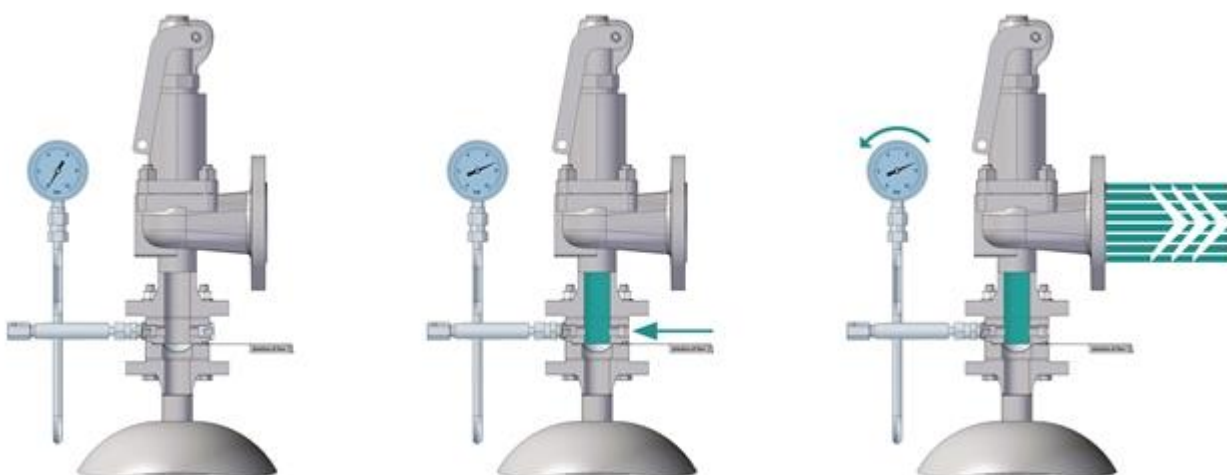
In-situ test: The space between the rupture disc and the safety valve is pressurised in order to test whether the safety valve is functioning correctly.

A SUMMARY OF THERMODYNAMIC FUNDAMENTALS

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Thermodynamics - the science that is concerned with **energy**, particularly **'energy-in-transit'** in the forms of **heat** and **work**, and those **properties** of **systems** that are related to energy.

Energy – the ability to do work. **All energy is *relative*!** Energy-in-transit is not relative.

Three kinds of energy:

(1) potential - energy due to *relative* position,

(2) kinetic - energy due to *relative* velocity,

(3) internal - the sum of all potential and kinetic energies of constituent parts [atoms, molecules, etc.] of a system.

Two kinds of 'energy-in-transit':

(1) heat – energy transferred between system and surroundings because of a temperature difference, or gradient.

(2) work - energy transferred between system and surroundings because of a pressure difference, or gradient.

Thermodynamic System – just "the thing" that we are talking about! Everything else is called the **surroundings**. The sum of the system and the surroundings is the universe.

Three kinds of systems:

(1) closed system – a fixed quantity of material; energy can cross the system boundaries but mass can not.

(2) open system – a particular region of space; both mass and energy may cross the system boundaries.

(3) isolated system (not an important concept) – neither energy nor mass may cross the system boundaries.

In elementary thermodynamics all systems consist only of atoms and molecules where the net electric charge of the system is zero. In addition, all electrical and magnetic and surface forces are generally neglected.

Thermodynamic Materials **- Systems composed of atoms and molecules are called** materials**. Two kinds of materials**:

(1) pure materials - composed of only one molecular species, and

(2) mixtures - composed of two or more molecular species.

ideal mixtures - mixtures where the volume and enthalpy of the mixture are simply the sums of the volumes and enthalpies of the pure components at the temperature and pressure of the mixture. Elementary thermodynamics deals only with ideal mixtures. Advanced thermodynamics is concerned with non-ideal mixtures, in phase equilibrium and reaction equilibrium.

Four basic concepts of materials:

(1) **Quantity**

   (a) mass (or weight in a known gravitational field)

   (b) number of objects (one gram mole = 6.025 x 10^23 objects)

mean-molar-mass (molecular weight or atomic weight) is the mass of one mole of a particular collection of objects, and is the constant which allow conversion between these two measures of quantity.

(2) **Composition** of a mixture

   (a) fraction - quantity of a particular species per unit quantity of the mixture.

   (b) concentration - quantity of a particular species per unit volume of the mixture.

(3) **Phase** - a homogeneous quantity of material, characterized throughout by a single set of thermodynamic properties.

   (a) solids - materials which are capable of resisting shear stresses.

   (b) fluids - materials which exhibit continuous deformation under shear stress.

     (c) liquids - fluids which can conform to their containers without occupying them completely.

     (d) gases - fluids which conform to and completely occupy their containers.

     (e) vapors - gases at temperatures less than their critical temperature.

quality - ratio of quantity of vapor to the total quantity of material [vapor & liquid] or [vapor & solid] in a system.

(4) **State** - defined by the **properties** of a material.

   (a) subcooled liquid (or compressed liquid) - a liquid at a temperature below its saturation temperature or at a pressure above its saturation pressure.

   (b) superheated vapor - a vapor at a temperature above its saturation temperature or at a pressure below its saturation pressure.

(c) <u>saturated</u> - if two or more phases exist within a system at **equilibrium**, the system is said to be saturated and all phases present are saturated. In particular, if vapor and liquid phases are both present within a system, the vapor is said to be **saturated vapor** and the liquid is said to be **saturated liquid**. Similarly, if two liquid phases exist within a system at equilibrium, both liquid phases are saturated.

<u>saturation pressure</u> (or <u>vapor pressure</u>) - the pressure at which a phase change will take place at a given temperature.

<u>saturation temperature</u> - the temperature at which a phase change will take place at a given pressure.

<u>critical point</u> - that state of a saturated system where the liquid and vapor phases become indistinguishable. The properties of a material at its critical point are the same for both vapor and liquid phases.

<u>equilibrium</u> - the condition of a system in which no net change in the properties of the system occur with time. A closed system is usually implied.

[<u>steady state</u> - no accumulations of matter or energy occur within the system. An open system is implied.]

<u>Thermodynamic Properties</u> - any quantity that depends only on the state of a material and is independent of the process by which a material arrives at a given state.

<u>Properties of a System</u> - the average or homogeneous properties of a system at equilibrium.

Two kinds of properties:

(1) <u>intensive</u> - independent of the quantity of material [T, P, Cp and Cv], and all specific and molar properties.

(2) <u>extensive</u> - directly proportional to the quantity of material [V, S, U, H, etc.].

<u>Pseudointensive properties</u> - extensive properties expressed per unit quantity of material [v, s, u, h, etc.].

Two kinds of pseudointensive properties:

(1) <u>specific properties</u> - expressed on a unit mass basis, and

(2) <u>molar properties</u> - expressed on a unit mole basis.

Five basic thermodynamic properties:

(1) <u>temperature [T]</u> (thermal potential) - a measure of the relative hotness or coldness of a material.

(2) <u>pressure [P]</u> (mechanical potential) - the normal (perpendicular) component of force per unit area.

(3) <u>volume [V]</u> (mechanical displacement) - the quantity of space possessed by a material.

(4) <u>entropy [S]</u> (thermal displacement) - the quantity of disorder possessed by a material.

(5) <u>internal energy [U]</u> - the energy of a material which is due to the kinetic and potential energies of its constituent parts (atoms and molecules, usually).

Two secondary thermodynamic properties:

(1) <u>enthalpy [H]</u> - internal energy plus the pressure-volume product.

(2) <u>heat capacity [Cp or Cv]</u> (specific heat) - the amount of energy required to increase the temperature of one unit quantity of material by one degree, under specific conditions.

    (a)   constant pressure $C_p = dh/dT$

    (b)   constant volume $C_v = du/dT$

Unlike gases, liquids and solids are nearly incompressible, and it is almost impossible to change their temperature while holding their volumes constant. The <u>specific heats</u> of liquids and solids almost always imply their constant pressure heat capacity (usually on a unit mass basis), so that, in general, for liquids and solids we used Cp.

<u>Gibbs Phase Rule</u>:   **F = 2 + Ns - Np**

F - <u>degrees of freedom</u> of the system = the number of *independent*,

   intensive <u>thermodynamic *variables*</u> (properties or compositions) which

   must be specified to fix the *intensive* state of the system,

Ns - number of molecular species within the system, and

Np - the number of phases within the system.

The thermodynamic variables specified as degrees of freedom are normally temperature, pressure and compositions (mole fractions) of the phases. Note that only [Ns - 1] compositions of each phase are *independent*. To fix the *extensive* state of the system, an additional *extensive* variable must be specified (i.e. total moles of the system).

<u>Thermodynamic Processes and Cycles</u>
<u>process</u> - any succession of events.

<u>chemical process</u> - a chemical or physical operation, or series of operations, which transforms raw materials into products.

<u>thermodynamic process</u> - the path of succession of states through which the system passes in moving from an initial state to a final state.

<u>polytropic process</u> - a thermodynamic process for which [PV^n] is constant. These processes are usually associated only to systems for which the ideal gas assumption holds.

Four special polytropic processes:

(1) <u>isobaric</u> - - - - - - - constant pressure [n = 0]

(2) <u>isothermal</u> - - - - - - constant temperature[n = 1]

(3) <u>isentropic</u> - - - - - - constant entropy   [n = gamma,(Cp/Cv)]

(4) <u>isochoric</u> (<u>isometric</u>) - constant volume   [n = infinity]

Two other important processes:

(1) <u>adiabatic</u> - no heat transfer.

(2) <u>isenthalpic</u> - constant enthalpy. This is the same as isothermal for an ideal gas system.

<u>reversible process</u> – an *idealized* process in which the deviation from thermodynamic equilibrium is infinitesimal at any particular instant during the process. All of the states through which a system passes during a reversible process may be considered to be equilibrium states. This is an *idealized* situation that would require infinite time and/or equipment size to be realized. The concept of a <u>reversible process</u> serves to set a maximum for the efficiency of a given process. Note that an *isentropic* process is an adiabatic-*reversible* process, so that real *isentropic* processes are not possible.

<u>thermodynamic cycle</u> - a process for which the final and initial states are the same.

Four common '*idealized*' thermodynamic cycles:

(1) <u>Carnot cycle</u> - isothermal and isentropic compressions followed by

       isothermal and isentropic expansions.

(2) <u>Rankine cycle</u> - isobaric   and isentropic compressions followed by

        isobaric   and isentropic expansions.

(3) <u>Otto cycle</u>   - isentropic and isochoric compressions followed by

       isentropic and isochoric expansions.

(4) <u>Diesel cycle</u> - isentropic compression followed by isobaric,

       isentropic and isochoric expansions

<u>Thermodynamic Data Presentation</u>
Data, such as properties of pure materials, is generally acquired by experimentation and can be presented in three fundamentally different forms:

(1) **Tables**   [i.e. the steam tables]

(2) **Graphs**   [i.e. a T-s or P-h diagrams]

(3) **Equations** [i.e. the ideal gas equation]

Each of these forms of presentation has advantages and disadvantages.

(1) <u>Tables</u> are precise but discontinuous, so that interpolation is often required. In addition, they can be bulky and can be difficult to use when implicit variables are specified. They also can require large amounts of data storage when used with computer programs.

(2) <u>Graphs</u> are continuous in their explicit variables but suffer loss of precision when they are of convenient size. In addition, they are discontinuous for implicit variables, so that imprecise visual interpolation is often required. They also suffer in readability as the number of implicit variables displayed increases above three or four. Although they can give an excellent overall "feel" for the data, they are virtually useless for computer purposes.

(3) <u>Equations</u> are in many ways the best form of presentation for data. They allow mathematical manipulation, are easy to use with computer programs, and are as precise as the data used to generate their constants. However, equations that accurately represent significantly large ranges of data can be very complex and usually employ a number of constant terms. Complex equations are usually difficult to solve for their implicit variables and often require trial and error procedures in their use. They are most suited for use in computer programs.

Thermodynamic Laws

A physical law is a simple statement of an observable physical phenomenon that has no underlying, more-basic reason for being except that the most accurate observations have always proved it to be true.

Laws of Thermodynamics

<u>Zeroth</u>: Two bodies in thermal equilibrium with a third body are in thermal equilibrium with each other. (This ?Law? simply states that 'thermometers work'.)

<u>First</u>:   A Simple Statement: Heat and work are both forms of energy in transit, and energy is always conserved. **or**

A Classical Statement: During any cyclic process on a closed system the cyclic integral of heat is always equal to the cyclic integral of work.

<u>Second</u>: <u>Simple Statement #1</u>: Spontaneous fluxes always take place down their corresponding potential gradients. **or**

Simple Statement #2: Heat and work are both forms of energy in transit, but they are not qualitatively equal forms of energy because work can always be converted entirely into heat, but heat can never be converted entirely into work. **or**

Kelvin-Plank Statement: It is impossible to construct a device which operates in a cycle and produces no effect other than the raising of a weight and the exchange of heat with a single reservoir. **or**

Clausius Statement: It is impossible to construct a device which operates in a cycle and produces no effect other than the transfer of heat from a cooler body to a hotter body.

Albert Einstein considered the Second Law of Thermodynamics to be the **only** real physical law.

<u>Third</u>:   The absolute entropy of a pure, crystalline material at a temperature of absolute zero is zero. (This ?Law? is the second half of the definition of entropy.)

Other Laws of Importance in Thermodynamics

Conservation of Matter: Matter can be neither created nor destroyed but only changed from one form to another. Note that Albert Einstein showed that matter could be 'destroyed' by converting it into energy.

Joule's ?Law?: The internal energy of an ideal gas is a function of temperature only.

Avagadro's ?Law?: Equal volumes of different ideal gases at the same temperature and pressure contain the same number of molecules.

Thermodynamic Processes • the process is any change from one equilibrium state to another. (If the end state = initial state, then the process is a cycle) 6 • the process path is a series intermediate states through which a system passes during the process (we very seldom care what the process path is) • processes are categorized based on how the properties behave: – isobaric (P = constant) – isothermal (T = constant) – isochoric or isometric (V = constant) – isentropic (s = constant) – isenthalpic (h = constant) – adiabatic (no heat transfer) Stored Energy • how is energy stored in matter? Stored Energy = E = KE + PE + U • Kinetic Energy: Energy due to motion of the matter with respect to an external reference frame (KE = $mV^2/2$) • Potential Energy: Energy due to the position of the matter in a force field (gravitational, magnetic, electric). It also includes energy stored due to elastic forces and surface tension (PE = mgz) • Internal Energy = microscopic forms of energy, U) – forms of the energy in the matter due to its internal structure (independent of external reference frames) Transit Energy Heat • transit form of energy that occurs when there is ΔT (a temperature gradient) • notation - Q (kJ), q (kJ/kg), Q˙ (kW), q˙ (kW/kg) Work • transit form of energy that occur due to all other driving forces.

Phases of Pure Substances • a pure substance may exist in different phases, where a phase is considered to be a physically uniform • 3 principal phases: Solids: – strong molecular bonds – molecules form a fixed (but vibrating) structure (lattice) Liquids: – molecules are no longer in a fixed position relative to one another – molecules float about each other Gases: – there is no molecular order – intermolecular forces ≈ 0

Basics of pump

1. 1. Pumps Basic Terms Definition Types Principal of Operation Major components & their Function Terminology Hammad Akber GTE
2. 2. Basic Terms • Volumetric Flow rate: Flow rate /Capacity of a pump is the amount of liquid delivered by the pump per unit of time (m3/hr). • Total Head: It is term that defines how high the pump can lift a liquid./Pressure in terms of height. • Hydraulic Power: Power transferred by the pump to the liquid. • VACUUM: Pressure lower than the atmospheric pressure.

3. 3. Definition • Pump: When a fluid has to be "moved" in a system, pumps are used. The pump is a machine which has the function of increasing the total energy of a liquid; this means that the pump transfers energy to the fluid that it receives from the driving motor". Need Of a Pump: ¬ Used to pump a liquid from lower pressure area to a High pressure area. ¬ To increase Flow rate. ¬ To move liquid from lower elevation to higher elevation.

4. 4. Types Displacement Pumps Centrifugal Pump Reciprocating RotaryPumps Dynamic Pump Radial Mixed Gear ScrewPiston Diaphragm Lobe Axial Vertical Horizontal

5. 5. Principle of Operation • Dynamic Pump: . In dynamic pumps, energy is added to the fluid continuously through the rotary motion of the blades. This increase in energy is converted to a gain in Pressure Energy when the liquid is allowed to pass through an increased area.

6. 6. Centrifugal Pump • Working Principle: Works on the principle of centrifugal force. This is the force that pushes the liquid away from the centre(in tangential direction). Converting Prime Mover energy into Mechanical energy through shaft . Converting Mechanical energy into fluid energy impeller. Converting kinetic Energy into pressure energy through the volute casing.

7. 7. Centrifugal Pump • Major Parts: • Shaft: It transmit the torque/Power. and supporting the impeller and other rotating parts. Shaft is protected from erosion ,corrosion and wear at the seal chamber through renewable sleeve. • Impeller: An Impeller has vanes that pushes the liquid through the impeller. Transmit energy into the fluid (hydraulic energy). • Volute/Casing: Impeller are fitted inside the casing. Volute casing is a curved shaped ,increasing in cross sectional area. Volute reduces the velocity of the liquid and increases the pressure.

8. 8. Major Parts Volute Casing Impeller/ Blades Shaft

9. 9. Types Of Impeller OPEN SEMI OPEN CLOSED

10. 10. Major Parts

11. 11. PARTS Wear RingsGland Packing Lantern Ring

12. 12. GLAND PACKING Lantern Ring Wear Ring

13. 13. • Radial Pumps: High Pressure& For low flow rate/Centrifugal pump. • Axial Pumps: Axial- flow pumps operate at much lower pressures and higher flow rates than radial-flow pumps. • Mixed Flow Pumps: Mixed-flow pumps operate at higher pressures than axial- flow pumps while delivering higher discharges than radial-flow pumps.

14. 14. • Why Centrifugal Pumps Need Priming? Centrifugal pumps does not create suction at the start without impeller filled with water. Hence Priming required . Priming is the process in which the impeller of a centrifugal pump will get fully sub merged in liquid without any air trap inside. This is especially required when there is a first start up. But it is advisable to start the pump only after primping.

15. 15. Multistage Centrifugal Pumps. In order to achieve a higher discharge pressure multiple impellers are used within a single pump. Depending upon the requirement. • `

16. 16. Vertical Pumps

17. 17. Positive Displacement Pumps • Working Principle: Positive Displacement Pump has an expanding cavity on the suction side of the pump and a decreasing cavity on the discharge side. Liquid is allowed to flow into the pump as the cavity on the suction side expands and the liquid is forced out of the discharge as the cavity collapses.

18. 18. Gear Pumps Working Principle:

19. 19. Screw Pumps • Working Principle:

20. 20. Lobe Pump • Working Principle

21. 21. Reciprocating Pumps: Working Principle Reciprocating Positive Displacement Pump

22. 22. Displacement Vs Centrifugal • Centrifugal pumps are suitable for low head and high flow rate. • PD pumps produce high head and low flow rate. • PD are suitable for High Viscosity application. • Centrifugal Pumps are not recommended for high viscosity application because as viscosity increases its flow deceases. • Usually a relieve valve is attached with the displacement pumps.

23. 23. Related Terminologies Cavitation: It is the process in which bubbles are formed due to sufficient Pressure drop at the suction of the pump. Bubble Formation inside a pump. Growth of bubbles. Collapse of bubble. Cavitations. Produces shock waves. ¬ Overhung Pumps: ¬ Between Bearings Pumps: ¬ Closed Coupled:

Q: Which Pump is more Efficient Centrifugal Pump or Reciprocating Pump?
Ans.: Centrifugal pump. Because flow rate is higher compared to reciprocating pun
Flow is smooth and it requires less space to install. Lower initial cost and lower
maintenance cost.

Q: One litre = _____ cm3 .
Ans.: 1000 cm3 .

Q: What is cavitation?
Ans.: Cavitation is the formation of vapor cavities (Air bubbles) in a liquid.

Q: How Cavitation can be eliminated in a Pump?
Ans.:
• Increase the Pump size to One or Two Inch,

• Increase the pressure of the Suction Head,

• Decrease the Pump Speed.

Q: What is kinematic viscosity?
Ans.: The kinematic viscosity is the ratio of absolute viscosity to the density of the
liquid.

Q: Differentiate between the Uniform Flow and Non-Uniform Flow?
Ans.:
Uniform Flow: The flow is defined as uniform flow when in the flow field the velocity
and other hydrodynamic parameters do not change from point to point at any instant of
time.

Non-Uniform Flow: When the velocity and other hydrodynamic parameters changes
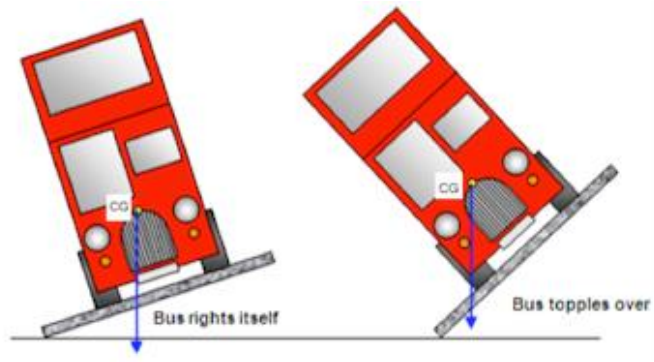from one point to another the flow is defined as non-uniform flow.

Q: What is the difference between the unsteady uniform flow and steady uniform flow?
Ans.:
Unsteady uniform flow - changes with time.

Steady uniform flow - does not change with time.

1) Heat engine

2) $X^2 + 5 = 0$, What is the value of X, X+2=6, What is the value of X

3) Centre of Gravity force

Bus rights itself

Bus topples over

4) Free body diagram

5) Cube top view, and Front view

6) Thermodynamic law 1 st,2nd, 3rd law

7) Fluid mechanics Type of flow

8) Pump alignment

9) Dynamics

10) Thermal engineering