WORKING PRINCIPLE OF HOMOGENIZERS

What is a Homogenizer?

A homogenizer is a mixer used to create a uniform and even mixture by forcing material through a narrow, confined space. Multiple forces such as turbulence and cavitation, in addition to high pressure, are used to distribute the contents of a solution evenly. Homogenizers have a positive displacement pump and homogenizing valve assembly. The pump forces the material to be processed under pressure through a small gap between the valve seat and the valve. The force of the pressure and the movement through the valve causes turbulence and mixing. Multiple industries rely on homogenizers to produce stable, uniform, and consistent products. Aside from mixing, homogenizers are used for emulsifying, suspending, grinding, dispersing, and dissolving. The pharmaceutical, beverage, and chemical industries rely on homogenizers for the production and quality of their products.

Homogenizers are used with high shear mixers, batch mixers, and paddle mixers and are installed downstream to create finer mixtures. However, some homogenizers cannot accept products with highly coarse components due to the risk of high energy consumption, decreased flow rate, heat generation, and increased material wear. Upstream of the homogenizer, mixers condition and prepare materials by premixing them.

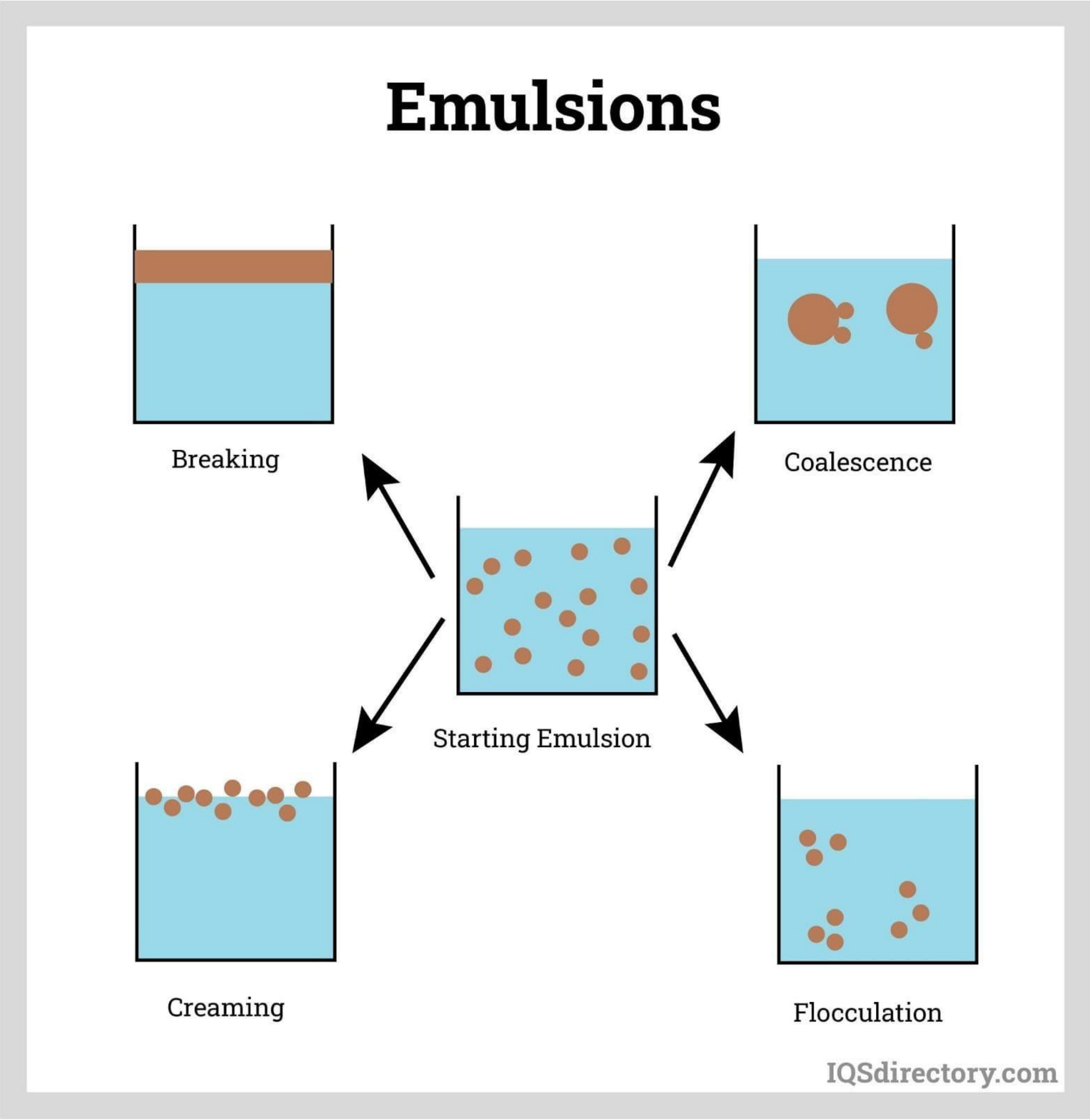
Homogenizer Theories and Principles

Several theories have developed over the years regarding the process of homogenization using high pressure. The two most prominent surviving theories are the globule disruption by turbulence and cavitation theories. These two remaining theories offer good examples of the influence of various forces on the homogenization process.

The theory of globule disruption by turbulence or micro whirls is built on the idea that a liquid jet forms at the outlet of a gap, with small eddies forming as the jet breaks up. As pressure increases, the velocity of the jets increases, producing smaller eddies with more energy. When a droplet in an eddy hits a droplet of its same size, it deforms and breaks up. The idea of this theory is that homogenization varies with the amount of homogenizing pressure.

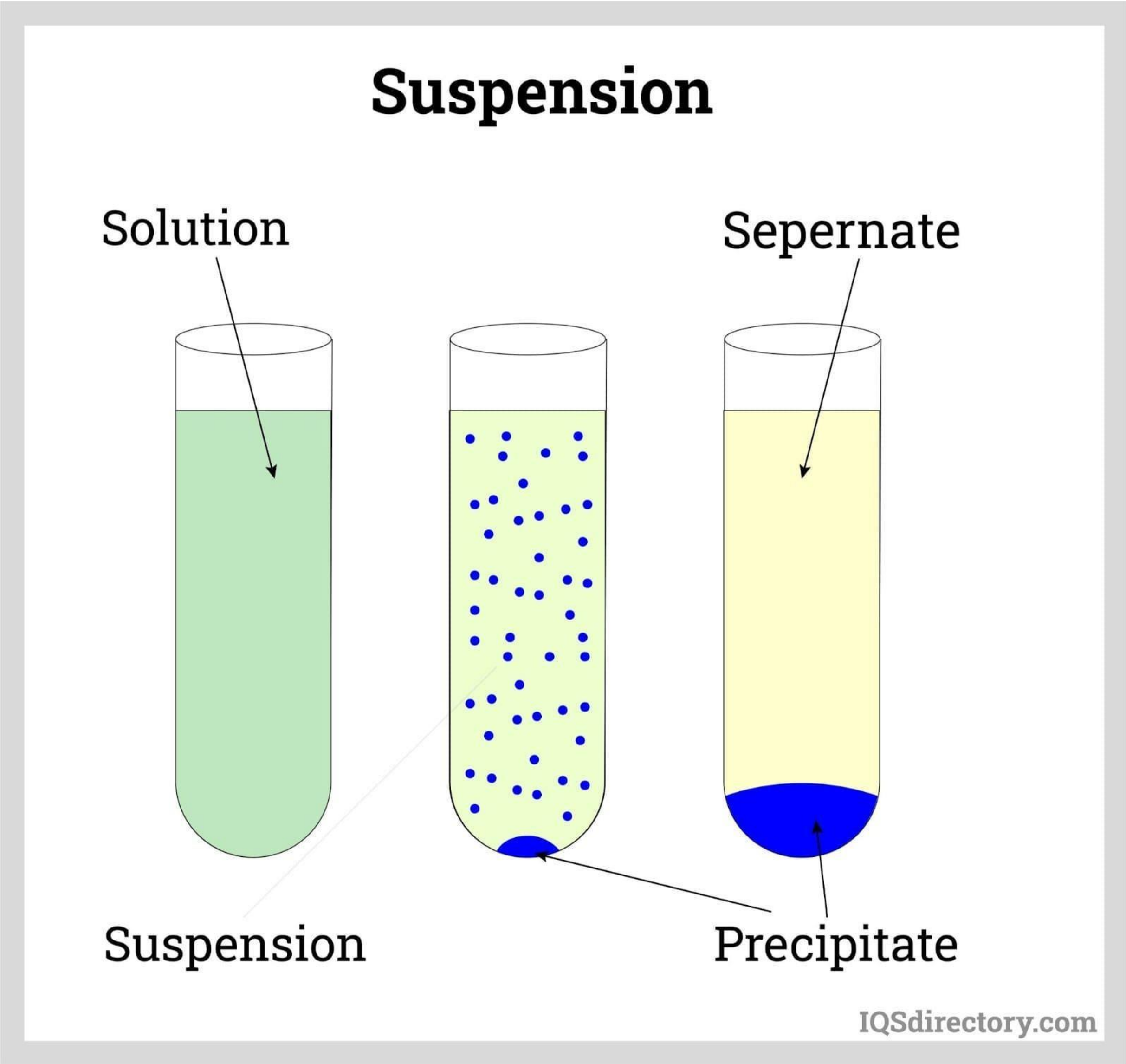
With cavitation theory, pressure changes during homogenization cause bubbles (cavities) in a liquid. As the bubbles grow, they implode or cavitate and release energy. The collapsing and imploding bubbles generate kinetic energy that surrounds particles in a liquid, creating high-speed jets that break up the particles. Bubbles collapsing on the surface of particles send energy directly to the particles and break them apart. The process of collapsing and imploding bubbles creates turbulence in a liquid that results in cavitation.

Homogenizers are used to mix emulsions and suspensions. An emulsion is a mixture of two or more liquids that are normally immiscible due to their liquid-to-liquid phase separation. This liquid to liquid phase separation is brought by several physical mechanisms, such as surface tension, polarity or repulsion, and viscosity. Homogenized emulsions are sometimes called colloids, a term used to cover a broader mixture classification.



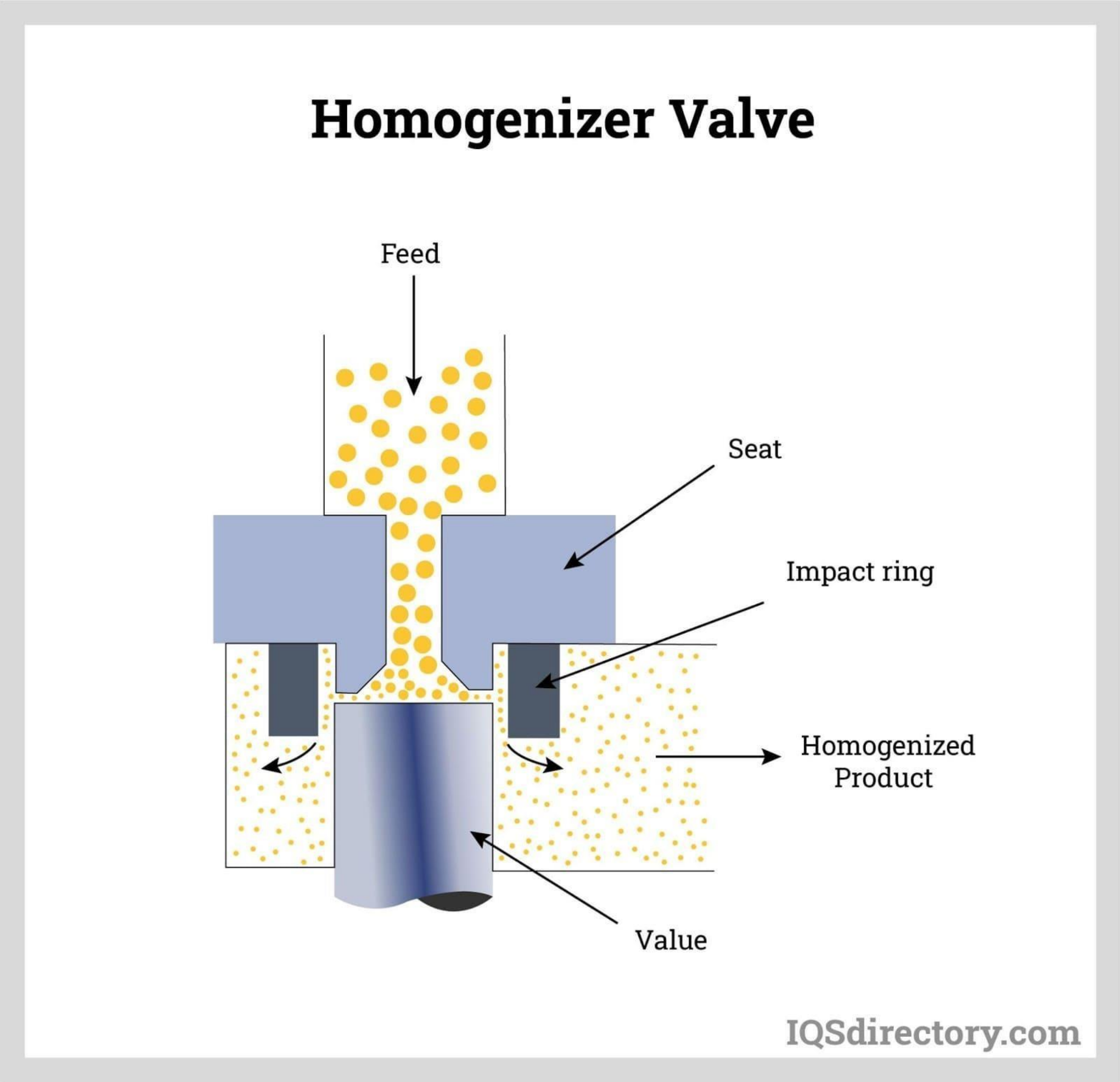
A suspension is a mixture composed of solid particles that settle down and cannot be dissolved completely in the mixture. The separation of the solid particles is brought about by their large size, which is around hundreds to thousands of times larger than that of the dispersed particles in a homogenous solution. Suspensions are non-homogeneous mixtures that disperse in liquids and are 100 times the size of the particles in a solution.

Particles in suspensions vary in size, with some particles visible to the naked eye. Homogenization supplies the force to combine suspensions with a solution and is one of its main functions.



Knowing the types of heterogeneous mixtures processed by a homogenizer, it is evident how a homogenizer works. A homogenizer works by breaking or subdividing the dispersed components into smaller particles and then distributing them evenly throughout the mixture. The action created by the homogenizer continuously disrupts the formation of large particles due to immiscibility and precipitation.

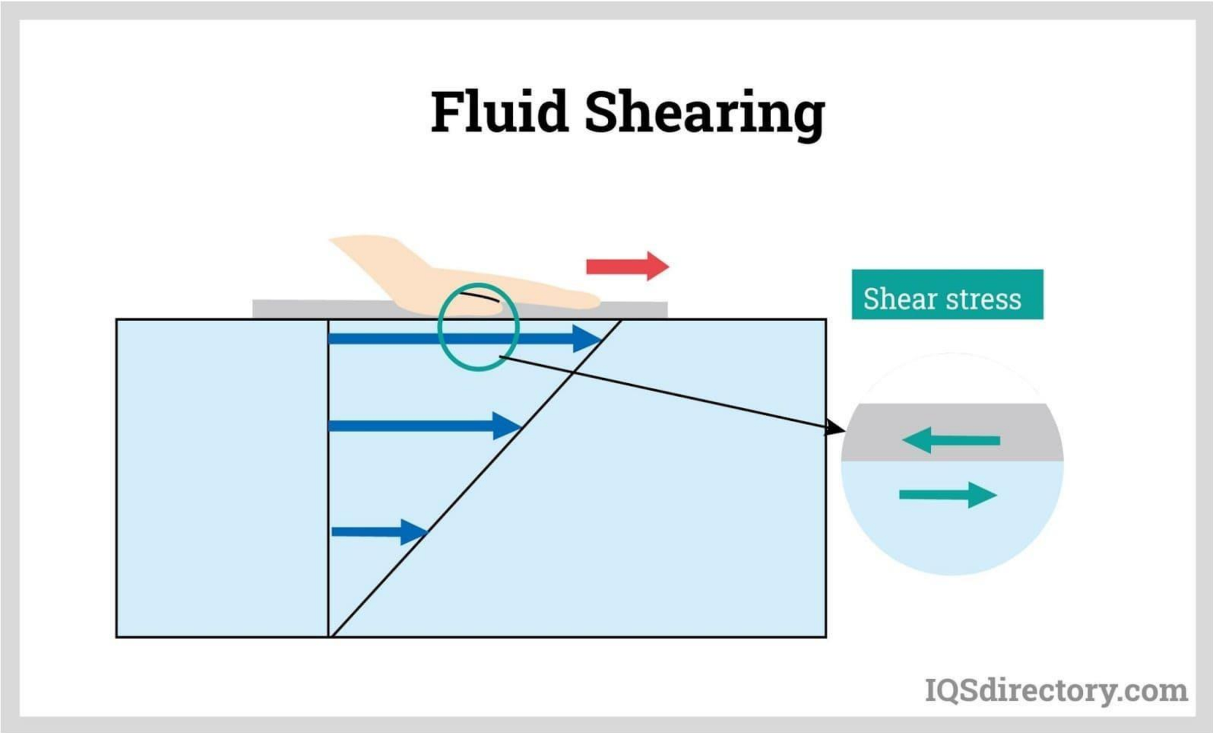
The homogenization process happens within the homogenizer valve, which is the main component of the equipment. Earlier, it was explained that the first homogenizer valve was an assembly with a capillary tube and a concave valve. The capillary tube throttled the fluid pressure and converted it into kinetic energy. The concave valve served as an impact surface for the fluid jet. Modern designs replaced the capillary tube with a seat that mates with the valve at an appropriate clearance to create a small gap for throttling flow. Within this gap, the fluid experiences the right flow conditions for homogenization through different physical principles.



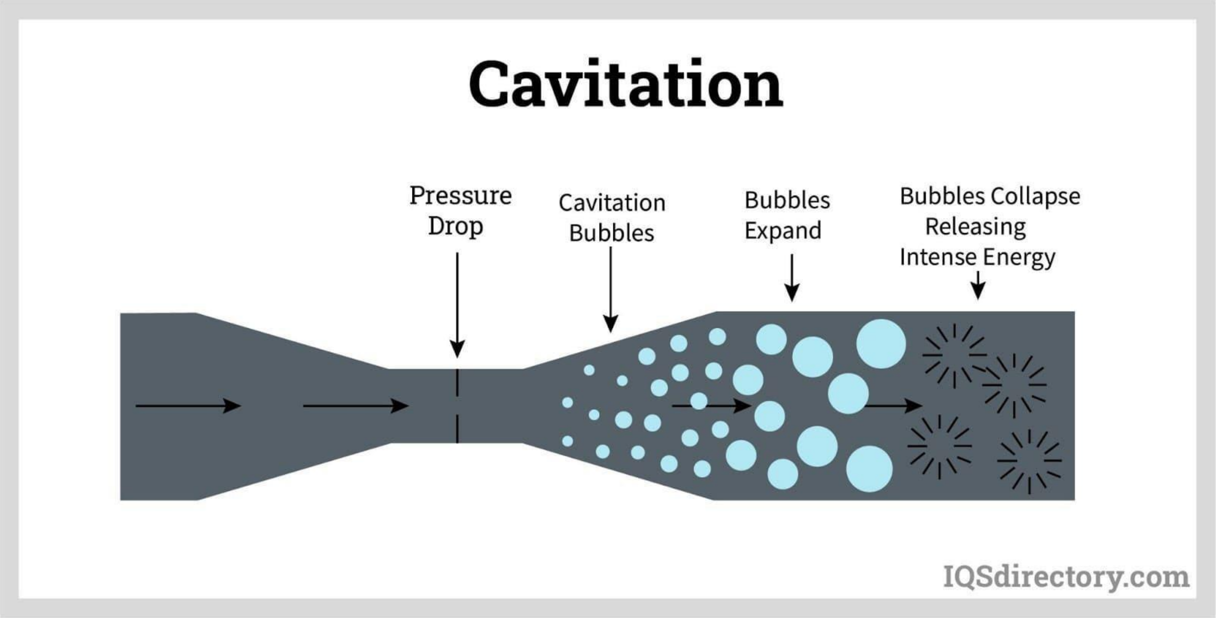
Homogenizing action is created by the combined effect of three main physical principles:

- Shearing
- Cavitation
- Turbulence

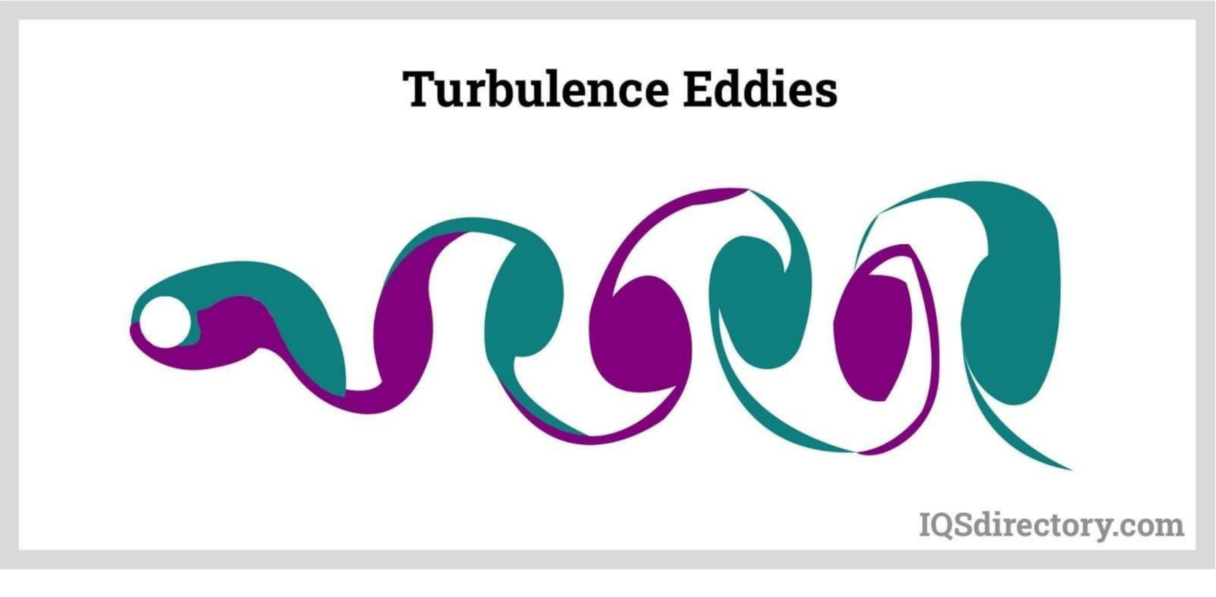
Shearing in fluids is primarily caused by friction between fluid molecules due to viscosity. In a no-slip condition, adjacent fluid molecules have the same velocity. However, when a disruption such as acceleration caused by a rotor-stator or deflection caused by an impact ring is present, different velocities develop because of the fluid's internal friction. At the boundary layer, or the layer between the homogenizer surface and the fluid, the velocity of the fluid is zero. Away from the boundary layer, the velocity of the fluid approaches the same magnitude as when the fluid was in no-slip condition. Shearing is experienced by a large particle or droplet when it is caught between fluid layers with different velocities. The shear forces break down large particles and droplets into smaller sizes.



Cavitation happens when a fluid experiences a large pressure drop. Typically, a pump that introduces the fluid at a higher pressure is located upstream of a homogenizer valve. The pressure of the fluid is converted into kinetic energy as it passes through the homogenizer valve. When the pressure drop is large enough, the vapor pressure of the fluid exceeds the absolute pressure inside the homogenizer. This allows the momentary formation of cavities from small pockets of vapor. Shockwaves are released upon the collapse or implosion of these cavities, breaking the particles and droplets in the mixture.



The last physical principle involved in homogenization is turbulence. Turbulence occurs when the fluid attains high velocity. The high velocity creates irregular motions within the fluid. These irregular motions are a form of energy dissipation wherein the kinetic energy of the fluid is converted into internal energy in the form of eddy currents and some amount of heat. The eddies generated help break the particles into finer sizes.



The extent to which each physical effect contributes to the homogenizing process depends on the design of the homogenizer valve and fluid properties such as temperature, pressure, composition, and viscosity. Still, most studies and experiments indicate that the turbulence effect is the primary mechanism for creating homogenization.

The generation of shearing, cavitation, and turbulence effects is not limited to a homogenizer valve. The other types operate differently than the original homogenizer but produce the same effect.