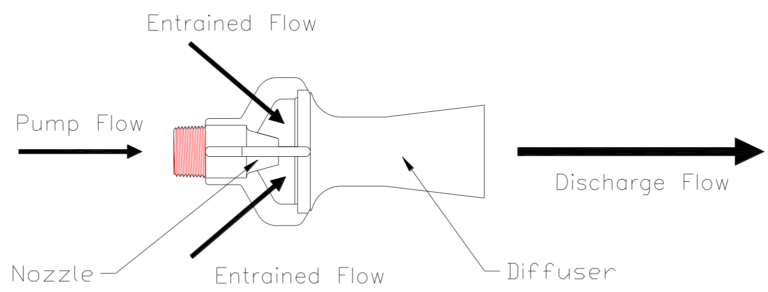
Eductor Operating Principles

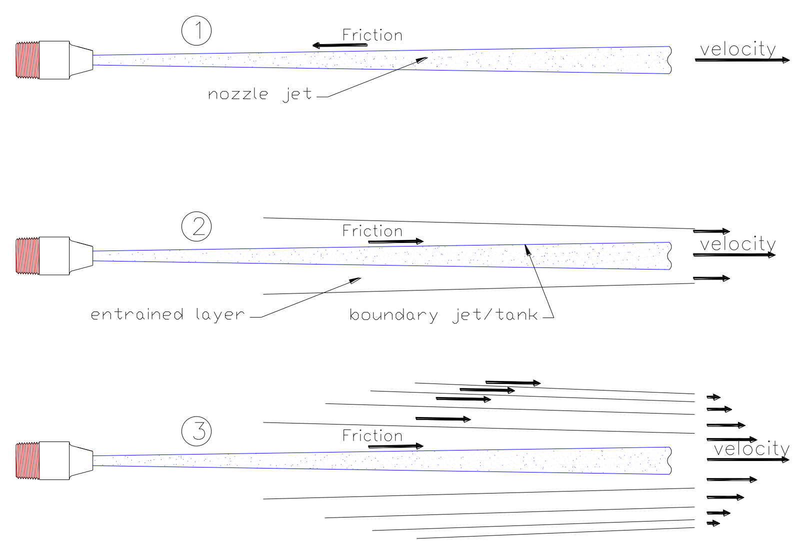
Basic Theory

An eductor uses a nozzle to produce a high velocity fluid jet to entrain the liquid surrounding the eductor (fluid can be either a gas or a liquid). The fluid in the nozzle jet and the entrained liquid are forced through a diffuser where the high throughput velocity creates a turbulent flow. The turbulence is very effective at mixing the fluid from the nozzle with the entrained liquid.



To better understand what an eductor does and does not do, consider what happens if an eductor is used without its diffuser section (nozzle only), and submerged in a liquid filled tank. The nozzle will still produce a high velocity jet of fluid. And the jet will still entrain liquid from the tank.

Why does this happen and what does it look like? See the sketch below.



The fluid in the nozzle jet is moving. Initially the liquid in the tank is not (view 1).

Friction occurs at the boundary between the moving fluid and the stationary liquid. This friction is a force which slows down the fluid in the nozzle jet. As there is an equal and opposite reaction for every action the friction also pulls at the tank liquid dragging it along with the nozzle jet (view 2).

At first only the liquid nearest the nozzle jet is affected. However, as soon as a layer of moving liquid is created around the nozzle jet, that layer starts to drag and pull at the stationary liquid which surrounds it. This creates a second layer of moving tank liquid which in turn creates a third layer and so forth (view 3).

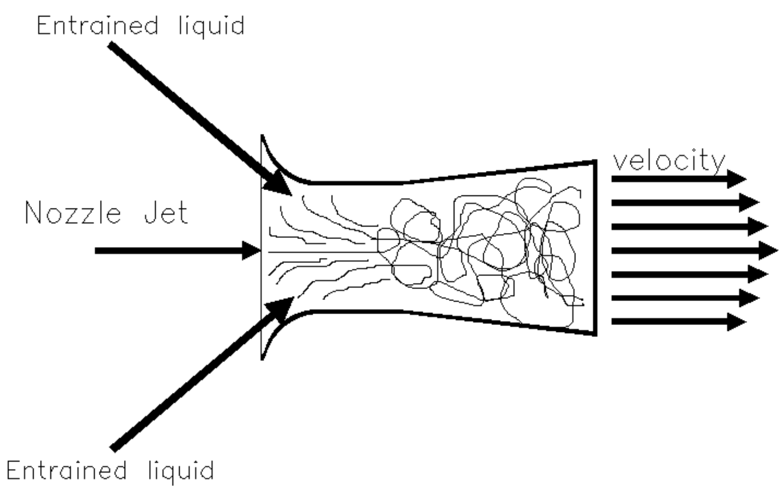
There are three points to note here.

First, the velocity of the layers decreases the further they get from the nozzle jet. Second, there is **very little mixing between the individual layers and the nozzle jet**. Third, friction between the layers of fluid transfers momentum from the nozzle jet out to the surrounding layers of tank liquid. This process is known as **momentum transfer**.

What happens when a diffuser is added to the nozzle section?

The nozzle still creates a high velocity plume. There is still friction between the nozzle jet and the tank liquid the jet encounters. However, the walls of the diffuser provide a definite boundary to the process of momentum transfer. The nozzle jet and the entrained liquid are confined to the diffuser and less volume of liquid is entrained by the nozzle jet.

However, because less volume is entrained, it is entrained at a higher velocity. In fact, the velocities through the diffuser are high enough that the flow through the diffuser becomes turbulent (see below).



The layers don't remain within neat, parallel boundaries, but rather tumble over one another in a random fashion as shown in the sketch. This physically mixes the nozzle jet with the entrained liquid, and greatly enhances momentum transfer from the nozzle jet to the entrained liquid. As a result, the mixture issuing from the discharge of the diffuser has a relatively uniform velocity across the width of the plume.

Common Misconceptions

An eductor acts like a pump to increase the flow rate you put into it.

A pump adds energy to a liquid. An eductor does not. In fact, the friction between the moving fluid and the walls of the eductor will take a small amount of energy out of the fluid.

The flow out the discharge of the eductor will be greater than the pump flow put into it by a factor of approximately five. However, the energy in the plume at the diffuser discharge will be slightly less than the energy at the eductor entrance.

There is also momentum transfer from the nozzle jet to the tank liquid, and an increase in total fluid flow from a simple solid stream nozzle.

The differences are:

1) With a solid stream nozzle there will be almost no mixing effect.

2) With a solid stream nozzle the plume will consist of a narrow, central nozzle jet at relatively high velocity surrounded by many layers of tank liquid at relatively low velocities. With an eductor the plume is homogenous and wider than the nozzle jet from a solid stream.

3) The momentum transfer is much more efficient with an eductor. Within four or five inches of diffuser length the kinetic energy of the plume is evenly distributed between the nozzle jet and the entrained tank liquid. The plume emerges with a uniform velocity profile with plenty of momentum left. Without a diffuser (i.e. a solid stream) the nozzle jet doesn’t finish transferring momentum to the tank liquid until the plume has just about stopped.

Using an eductor increases the agitation in a tank.

Using an eductor distributes the agitation more evenly around the tank, but it does not increase the agitation.

If we measure “agitation” by the amount of kinetic energy transferred from the pump to the tank, then an eductor will transfer slightly less energy to the tank than a solid stream nozzle.

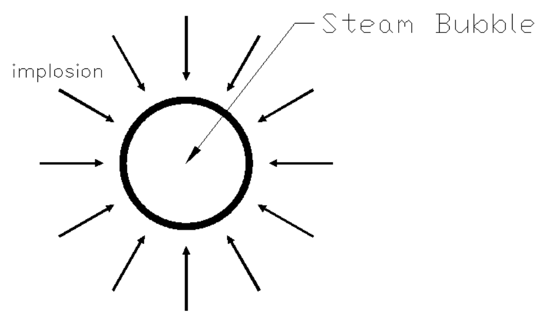
The advantage of an eductor is that the discharge plume is much broader than the jet from a solid stream nozzle of equivalent kinetic energy. As such, it distributes agitation to a larger volume of the tank than a solid stream nozzle.

Spargers

A steam sparger is any device used to inject steam into a tank liquid for the purpose of heating the tank liquid. Eductors make very effective steam spargers.

When steam is used to heat a tank liquid, there is the risk of damaging the tank due to cavitation of the steam bubbles.

Cavitation occurs when a steam bubble implodes. When steam is injected into a relatively cold liquid some steam bubbles cool down until they reach the temperature where water vapour liquefies. When the vapour in a bubble liquefies the volume occupied by the bubble decreases by a ratio of close to 1:1000.



This happens very quickly and it creates a hole in the tank liquid. Liquid rushes in to fill the hole. This creates a shock wave of moving liquid very similar to the shock wave created by an explosion.

Shock waves from multiple implosions are sometimes strong enough to damage a tank or its foundation.

The solution to cavitation is to break the steam up into very small bubbles to minimize the shock wave from each implosion.

An eductor does this through the mixing action in the diffuser. Steam is injected into the eductor and the nozzle section forms it into a high velocity jet. This jet entrains tank liquid in the normal way and the tank liquid and steam jet are mixed in the diffuser in the normal way. The mixing is so thorough that the steam bubbles in the eductor discharge are very small. As such the shock waves created when they implode aren't strong enough to do any damage.

In order for an eductor to be effective as a steam sparger, there must be enough steam pressure supplied to the eductor to create a high velocity steam jet out of the nozzle.

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