

Kinetic Energy Separation

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Introduction In the relatively limited array of devices that aid in the separation of contaminants from analyzer samples and the principles that govern them, the kinetics of the control volume are likely the most overlooked. Rivalled only by the filter, kinetic principles are the most versatile with regard to application, range of pressure, rate of flow, and fluid densities, which can be accommodated. While the laws of classic Newtonian physics govern the operation, it can incorporate filter, boundary shear stress, membrane, and temperature technology while maintaining an acceptable lag time.

Theory of Separation Kinetic separator technology takes advantage of differing densities to accomplish separation. A denser contaminant particle in a sample stream will possess a higher inertial force. Consequently, it will continue in the flow stream while system pressure and flow path contours force the lighter components to flow toward a low pressure port above the sample outlet. See figure 1.

In a flowing process stream, the condensate and solid particulates in a gaseous sample, and the heavy immiscible liquids and solid particulates in a liquid sample will tend to remain in the fluid stream, while the lighter more representative components will separate from the contaminated stream. After separation, the kinetic separator returns the remaining sample to the original process stream while the representative sample is sent to a polishing chamber for further purification. The separator functions at full system pressure to optimize inertia while keeping the flow high, thus minimizing lag time. Unlike most conditioning devices, kinetic separators have also been found to function satisfactorily in a low flow and/or low pressure application with a minimum of lag time.

Separation/Performance Kinetic technology performance can be improved with consideration of another largely overlooked principle. It is common knowledge in knock-out technology that a polished surface will separate contaminants and water more efficiently than a rough surface. Water has a high surface tension due to intermolecular cohesive attraction. Polymers such as PTFE Teflon® have a very low coefficient of friction. When the inside chamber of a kinetic separator is lined with PTFE Teflon®, the smooth walls improve separation at low flow rates. At high flow rates, the low surface friction of the PTFE Teflon® will allow the condensate to traverse the length of the inner wall without defusing to smaller particles, allowing the solid contaminants to move through unobstructed.

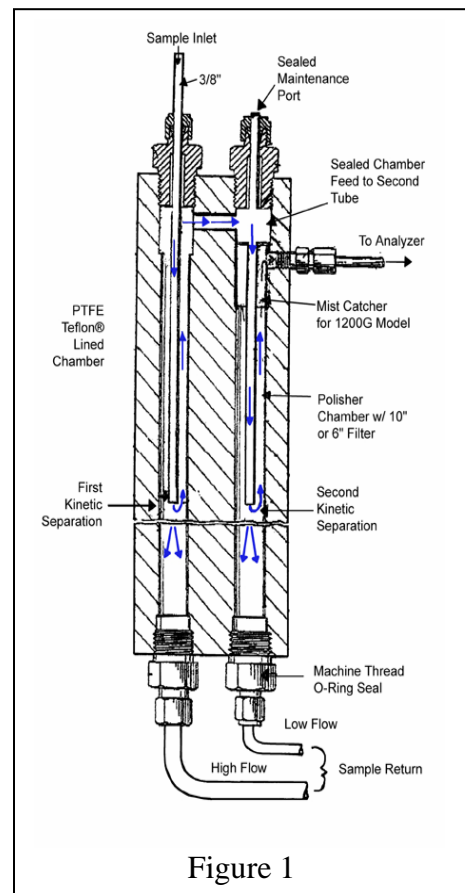


Figure 1

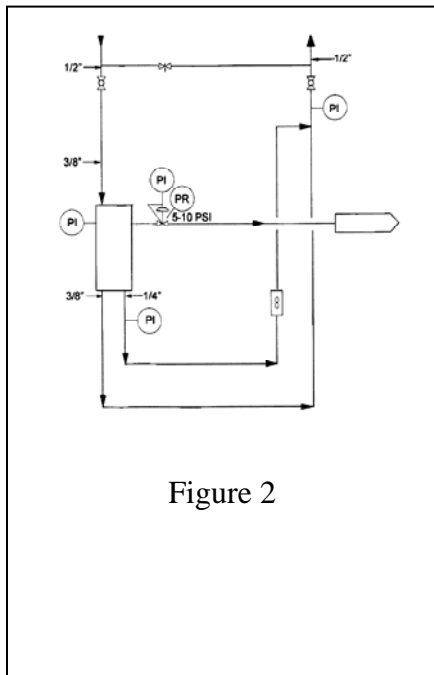


Figure 2

To further improve separation, a second kinetic chamber is added for additional decontamination with minimal additional lag time. The flow rate of a single chamber separator will be governed by analyzer requirements. For lag time calculations of the first chamber, only the slipstream flow, which reversed direction, is applicable. This flow is determined by the exit flow of the second chamber. Although the flow rate is substantially lower than the fast loop exiting the first chamber, the optimum flow rate is at least ten times the flow to the analyzer. See figure 2. The lag time for a stand alone, single chamber kinetic separator is 16 seconds with a typical 100 psi fast loop with 2.5 scfh flow to the analyzer. When a second chamber is added, with 25 scfh exit flow from the bottom of the second chamber, the lag time for the first chamber becomes 2 seconds and the overall lag time is 18 seconds. Thus, for a cost of an additional 2 seconds lag time, a second polishing chamber can be added.

Although the flow rate in the second chamber is approximately 1/10th that of the first chamber, it is sufficient flow to utilize inertia. In addition, the reduced velocity will allow liquid droplets to separate by gravity as is common with knock-out technology, without the excessive lag time associated with the larger knock-out separators. In addition to the lower volume of the kinetic separators “another very important factor to be considered is the mixing effect within components (other than pipe or tube) of the sample conditioning system. Where the ratio of height to diameter (both internal) is greater than 10, mixing lag is not a factor.” The lower flow of the second chamber also allows for the utilization of temperature, filter, and/or membrane coalescing technology.

Filtration A sealed chamber at the top of the second chamber allows the process to flow into a tube in the second chamber via openings in the tubing walls. A long narrow filter housing is created below the seal similar to the Cylindrical Bypass Filter but with a vertical orientation. The outlet port to the analyzer is located just below the sealed chamber. A standard 1/2” filter specifically fitted to the length of the lower second chamber is used. Because the filter seats on the bottom of the chamber, the flow moves down the inside of the filter, providing “a scrubbing action to keep the inside of the tube clean. By ensuring that the major flow is over ten times the filtered sample flow, particles are made to impact the filter element at a shallow angle. This, together with the momentum effect of the fast stream, helps to increase the efficacy of the filtration without clogging the element.”² The analyzer sample must first change direction and then permeate the filter wall as the main flow carries the heavy contaminants down and exits the bottom port.

Pressure Drop The differential pressure in the second chamber is never more than 2-psi at any point because the analyzer exit flow and the polisher chamber exit flow are controlled by rotometers, which maintain backpressure. The benefit is a filter in the second chamber can coalesce free water droplets more efficiently, and particles are not as likely to adhere to the filter wall if a high differential pressure is not forcing them through. This phenomenon compliments the low flow that is typical of analyzer specifications. Low differential pressure and low flow to the analyzer are the requisites for good coalescing of water across a filter in gas or liquid applications. It should be noted “sample velocity is critical in the operation of coalescing filters since Stoke’s Law will preclude phase separation if the sample velocity is too high and the phase density difference is too low.”² This is particularly relevant when the filter is constructed of selective membrane materials such as PTFE Teflon[®] designed to repel water.

Temperature Effects The effect on sample temperature is observed at the ends of both supply tubes to the chambers. In the first chamber, the process enters a 3/8" tube and is expanded to 3/4". The same is true of the second chamber, which enters the lower section in a 1/4" tube and is expanded to a 1" chamber. As anticipated by Boyle's Law, this expansion creates cooling at the end of the separator. It does not appreciably cool the body because of the insulating characteristics of the PTFE Teflon® lining. For nominal sample temperature control, a Vortex cooler can direct cool air at the separator body to achieve external cooling. Alternately, and more often recommended, sample temperature can be controlled more precisely with a Peltier cooler in a more localized area of the second chamber. Cooling the sample results in condensation, allowing condensate to exit the bottom due to gravity and inertia of the sample flow. Cooling as a means of increasing differences in phase density will likewise enhance liquid separation.

Conclusion The basic criteria for a sample handling device is to deliver a representative sample compatible with the analyzer with an acceptable response time in a safe, reliable, and cost effective manner.² A representative sample may vary from the exact composition of a sample stream within predetermined and acceptable tolerances. Much of the same trade off exists to meet compatibility demands "for ideally representative sampling, the sample would be presented to the analyzer in exactly the same condition as it exists in the process. Most analyzers however, require that the sample be modified in some way to make it compatible with the technique of measurement (e.g., cooling, pressure reduction, and condensate removal)."² The underlying theme for representative and compatible samples is a pragmatic approach using only the tools necessary. This is easily accomplished with kinetic separation. A separator can be specified with only the options necessary to meet compatibility issues, which will preserve the sample in a state with predictable differences from the unconditioned stream. The components removed by kinetic separation are too heavy to be considered a part of the analysis and will not be compatible with any but select analyzers such as those on a water stream. After the initial separation, the techniques of filtration, membrane separation, or cooling can be used if and when appropriate.

The distance-velocity lag of the sample transport system is limited only by the physical constraints of the system. The straight through nature of the first chamber does not inhibit the flow. Kinetic separator lag time is minimized in both fast loop and single line applications. Both applications benefit from the lack of first order lag time consideration and the low volume of both chambers. The fast loop benefits from the significant flow exiting both chambers and the single line benefits from a reduced compressibility factor.

The kinetic separator can be constructed of varying material, to meet compatibility requirements of the service. The only maintenance required is filter replacement. The kinetic separator is a sealed system at ground level rated for high pressure service, and returns all contaminants to the process in a fast loop application.

Kinetic separation is safe, simple, and cost effective, with relatively low initial cost and very low maintenance. Only one separator is necessary, with the options determined by the application. Options may also be added after installation. With only slight variations, the separator can be used in high or low flow rates, with a high or low pressure, and with liquid or gas applications.

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