

Advanced Servo Control Helps Pump Accurately Perform Under Pressure

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Positive displacement pumps have the advantages of accurate delivery with high-pressure capability while handling a wide range of materials. However, the standard reciprocating piston or syringe pump alternates between fill cycles and empty cycles, resulting in a start/stop of the flow stream or 100% pulsation. The Car-May-Encynova™ pump is a hybrid piston syringe pump with four cylinders. It has the advantage of continuous flow, with greatly reduced pulsation, by using four cylinders coupled to a single rotating crankshaft.

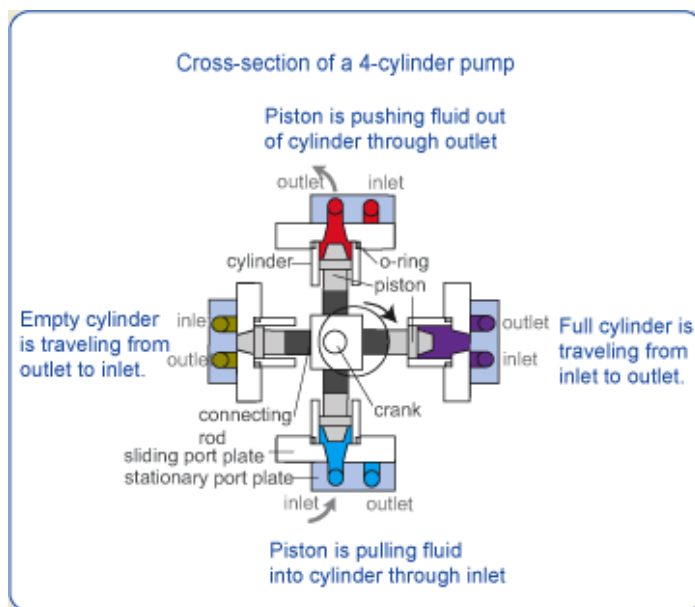
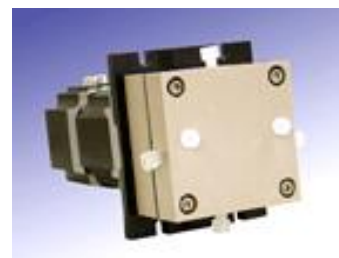
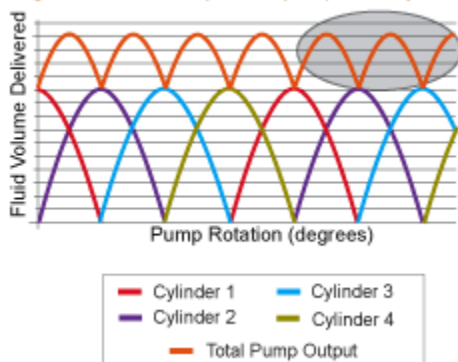


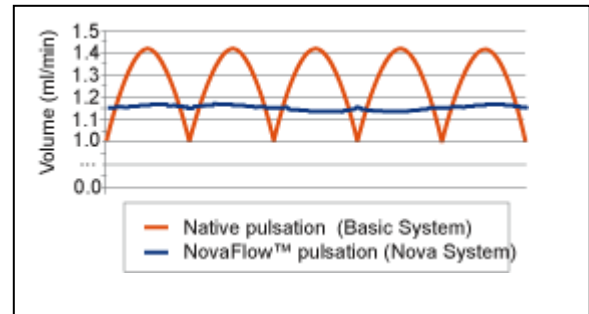
Diagram 1 shows a single rotating input shaft actuating the four cylinders as well as the four sets of sliding ceramic plates. As the crank rotates, at least one cylinder is being filled, and at least one cylinder is dispensing at any time, with two doing each function for the majority of the revolution. This design produces a continuous output flow from the pump. The resulting flow, however, still has slight pulsation levels of +/-15% at constant speed of crankshaft rotation. Figure 2 shows the idealized flow rate from a 4-cylinder pump operating at constant angular velocity. A real pump also has cylinder-to-cylinder variations. The pump displacement is a repeatable function of crank angle and is individually calibrated for each pump.

Figure 2: Native Liquid Output (Basic System)



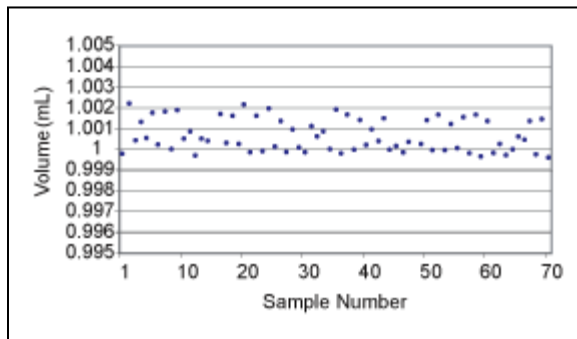
The SilverDust™ controller from QuickSilver Controls, Inc., uses this calibration table, loaded into onboard memory, to dynamically vary the pump velocity as a function of requested flow rate and pump dynamics.

The resulting NovaFlow™ system produces a nearly constant flow rate (<1% of total flow), even into varying pressure heads. The system may also be operated in volumetric mode to deliver requested volumes at requested delivery rates, with the volumes not limited by cylinder sizes. The intelligent Servo Controller uses these same calibration tables to determine starting and ending positions needed to dispense the desired volume.



The use of a continuous operating pump allows increased throughput in systems by eliminating the aspirate time normally required by piston or syringe pumps. Precision is improved by the valve-less design which use ceramics to channel the flow and prevent the backflow associated with other pump technologies, as well as undesired pulsations in flow rate. The pump is constructed of ceramic, Teflon™, glass and perfluoroelastomer O-rings which provides compatibility with a wide variety of fluids used in diagnostics and

pharmaceutical processing, to dispensing flavors for food processing and precision filling of inkjet cartridges.



The pump crank is directly driven from the motor, taking advantage of the high torque capability of the high pole-count motors employed in this application. The elimination of a gear-head reduces size, cost, and maintenance of the system. The Servo controller also allows extremely slow rotation

speeds at full torque producing a turndown ratio of 1:1,200,000 which is un-equalled by other pumps.

This high torque capability is produced by the use of high pole-count servo motors. A synchronous motor mechanically advances one pole pair for each electrical cycle of current applied to its windings. For a two pole motor, this is a full revolution, for a four pole motor, a half revolution, for a 100 pole motor, this is 7.2 degrees. Given the same magnetic path characteristics within the motor, the torque of the motor increases with the number of poles, just as the speed decreases. This effect is commonly referred to as Magnetic Gearing. In comparing a four pole synchronous motor to a 100 pole motor synchronous motor, everything else being the same, the 100 pole motor will produce 25 times the torque at one twenty-fifth the speed.



The 100 pole servo motors used by QuickSilver Controls, Inc., are two-phase AC permanent magnet motors, commonly deployed as open-loop steppers. The SilverDust™ operates these motors as AC servo motors providing the simplicity and high reliability of the stepper with the smooth and precise control of a servo system. The low speed resonance problems often associated with open loop step-motors are also eliminated (see sidebar). With closed loop control, these motors may be operated up to their full torque, where as in open loop they would normally only be used at 30% to 50% of their capability to prevent loss of synchronization. This both increases performance and minimizes motor heating.



### *What causes stepper low speed resonance?*

The low speed resonance of the open loop stepper is a result of the motor operating as a rotary spring-mass system about its equilibrium point. The motor torque is approximately a sinusoidal function of its position error. This “spring” interacts with the rotary inertia of the motor to form a rotary pendulum. As the motor is stepped (or microstepped) the equilibrium point is moved, causing the “pendulum” to seek the new equilibrium point. If the stepping rate approaches the natural frequency of this pendulum, the amplitude of the swinging increases, often causing the motor to lose synchronization with its drive signals.

When this same motor is operated as an AC servo motor, the commutation logic keeps the magnetic field positioned so as to produce the maximum torque for the commanded current magnitude. A perturbation of the rotor angle causes the commutation logic to shift the magnetic field by the same amount, keeping the force nearly constant. Without the position dependent torque term, the spring effect is eliminated as well as the associated low speed resonance problem.

The SilverDust controller also provides Anti-Hunt capability to prevent motor dither when stopped. These small constant re-adjustments common to servo systems would otherwise cause damage to the sealing surfaces of the pump. Anti-Hunt is performed by selectively switching to open loop operation when stopped and the error is sufficiently low, operating the motor again as a stepper. Larger errors cause the system to switch back to normal closed loop operation so position is never lost.

The unique capabilities of the SilverDust™ controller support the unique requirements of the Car-May-Encynova™ pump to provide precise flow and delivery in a positive displacement pump system.