

Valve Timing Intelligence for Vacuum Flow Control

A combined flow and vacuum system compensates for the shortcomings of traditional pumps.

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Since the introduction of intraocular ophthalmic surgery in the 1970s, 2 types of pumping and cartridge systems have prevailed: (1) venturi and (2) peristaltic. The former makes use of the venturi effect to create a vacuum. Vacuum is generated by the flow of air over an opening. The vacuum level is created within a rigid drainage cassette and is controlled entirely by a foot pedal; the resulting fluid flow depends on the viscosity, size of aspiration path, cut rate, and achieved vacuum value. In the occluded state, there is no difference between the 2 pump concepts: Vacuum is built to induce flow.¹⁻⁵

The peristaltic pump uses rollers to compress the outflow tubing in a peristaltic manner, thereby creating flow. Vacuum is generated only upon occlusion of the aspiration line. The compression of rollers on the flexible tubing together with rotation of the pump physically moves fluid and creates a continuous action on the fluid column; the flow is controlled by altering the rotation speed. When an occlusion of the aspiration line occurs, the pump continues to rotate, which builds vacuum. The pump rotation stops when the preset vacuum limit has been reached. Once the occlusion has been removed, the pump returns to the rotation speed to deliver the intended and preset flow volume.⁶⁻⁸

This article details the rationale, concept, and development of a new technology for flow control, VacuFlow valve timing intelligence (VTi; DORC).

RATIONALE FOR DEVELOPMENT

There were 2 primary reasons behind DORC's development of a different aspiration control system. First, with older systems, lag time was caused because the air volume of the often large (250 cc) cartridge had to

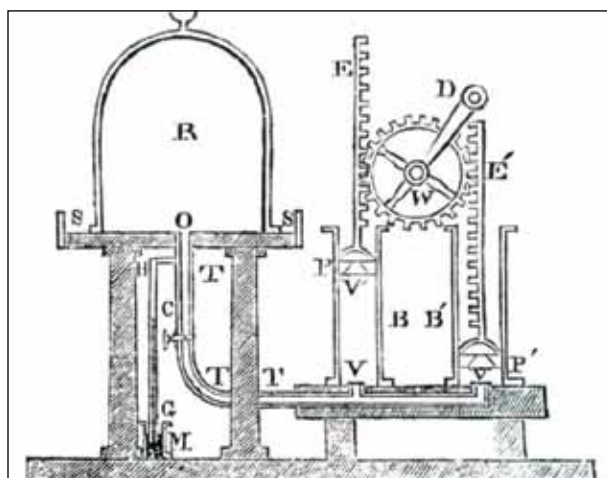


Figure 1. The piston-type vacuum pump was invented by Otto von Guericke in the course of a series of experiments on the production and effects of a vacuum. In his early experiments (circa 1647), von Guericke produced a vacuum by using a suction pump to remove water from a sealed wooden cask. The diagram shows the double-barrel air pump (right), which is dated from 1832 but was an old-fashioned design for the time. The valves labeled V and V' allow a certain fraction of the air remaining in the receiver to enter the pump barrel as the piston is drawn up and to be expelled as the piston goes down.

be removed before the desired vacuum level was built. Recently, platforms such as the Constellation Vision System (Alcon) have produced improvements in this regard with the creation of smaller mini chambers. However, the absence of true flow control, which is an inherent shortcoming of a venturi system, had yet to be addressed. The next evolutionary step, therefore, was

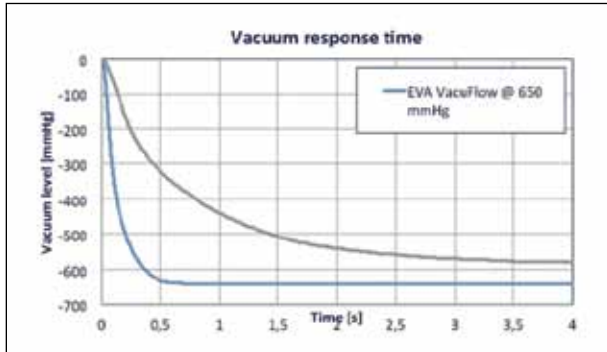


Figure 2. The image demonstrates decrease in vacuum level over time with EVA VacuFlow VTi at 650 mm Hg.

achieved by combining a series of very precise, computer-controlled operating pistons and closure valves working in very small “flow chambers.”

Second, a combined flow and vacuum system was deemed necessary to compensate the weaknesses of both peristaltic and venturi pumps. The venturi pump has never allowed precise, viscosity-independent flow control, whereas peristaltic systems characteristically produces mild flow fluctuations inherent to the rotary compression of flexible tubing.

PRINCIPLE OF PISTON VACUUM PUMPS

The operating principle of piston vacuum pumps, 1 of the oldest in the history of vacuum generation, is that of the classical positive-displacement pump. Otto von Guericke, the father of vacuum technology, used a pump incorporating this design for his experiments. The rotation of pistons and cylinders aligned at a small angle generates a relative stroke motion between them in the co-rotating reference system. The pistons, passing over the inlet port, suck in and at the same time push backward against the high working pressure in the housing. Pistons and cylinders rotate only and are counterbalanced. There are no mass forces. The piston rods, piston plate, and drive shaft are 1 solid piece without any bearings between them. Hydraulic forces are all hydraulically compensated (Figure 1).

VACUFLOW VTi FOR OCULAR SURGERY

VacuFlow VTi technology was introduced in 2012 by DORC for the EVA platform. The novel concept of the aspiration control system eliminates the need for a conventional cartridge, which is replaced with a unique micro-chamber system. In conjunction with this new micro-chamber system, computer-controlled pistons and valves work in harmony with high-precision pressure sensors.

There are 2 operating pistons and 3 closure valves. The



Figure 3. The 2 operating pistons and 3 closure valves. The operating pistons are situated over the micro-chambers. They operate in a synchronized manner and are constantly compensating changes in pressure, recognized by highly sensitive pressure sensors. Three closure valves, synchronized with the 2 operating pistons, allow the system to fill and empty the micro-chambers without any disruption in flow or pressure.

2 operating pistons are situated over the micro-chambers. These pistons operate in a synchronized manner and are constantly compensating changes in pressure, recognized by highly sensitive pressure sensors. Three closure valves, synchronized with the 2 operating pistons, allow the system to fill and empty the micro-chambers without any disruption in flow or pressure. The result is an optimal balance of pressure to block fluctuations in aspiration pressure, with an extremely fast ability to create vacuum from 0 to 650 mm Hg in less than 0.3 seconds (Figures 2 and 3).

The EVA system allows the user to decide between vacuum or flow control mode. In vacuum mode, the pistons work at high speed to build and maintain the desired vacuum value. In flow control mode, the valves operate at a precalculated speed to achieve the specific

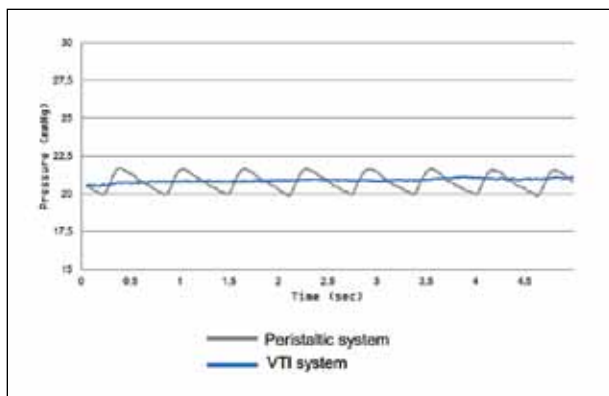


Figure 4. A comparison of 2 flow-driven pump systems. A peristaltic pump generates fluctuations in flow due to the rotary aspect of its design. The VTi system in flow mode provides a stable aspiration flow.

desired flow. The result is a highly synchronized system that enables the exact control of aspiration and flow with excellent precision (Figure 4).

In flow mode, the EVA platform is able to control flow to within 0.1 cc accuracy—around 1000% more precise than earlier machines. The vacuum response time is 4 times faster than previous pump technologies.

SURGICAL EXPERIENCE

Since October 2012, more than 500 surgical cases have been performed using the EVA platform, including vitrectomy cases, phacoemulsification procedures, and combined phaco-vitrectomy surgeries. Several findings have been noted, as described below.

No. 1: During phacoemulsification surgery, the fast vacuum rise time in the vacuum mode can provide quick and powerful attraction of the lens particles during segment removal, which reduces the amount of phaco power needed by around 30%. Moreover, a built-in vacuum thresholding system rapidly reduces the amount of aspiration when the occlusion of the phaco tip breaks (fragmentation of the lens piece); this eliminates a surge in aspiration that can induce the collapse of the anterior chamber.

No. 2: During core vitrectomy, working in vacuum mode with either high or even relatively low cut speeds (1500 to 3000 cuts per minute), the core vitreous can be removed very quickly. For vitreous base shaving, the EVA device can be set to flow mode with very low fluid displacement, usually in the setting region of 0 to 4 cc/min and precisely controlled by the foot pedal.

No. 3: In combination with ultrahigh-speed cutters (up to 8000 cuts per minute), using high-flow technology, the vitreous can be removed up to the vitreous base

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virtually with no traction, avoiding the creation of additional retinal breaks, even when working on a detached retina.

CONCLUSION

At first glance, the VacuFlow VTi appears to be relatively simple technology; however, at the heart of this platform is a highly developed computer-controlled system. The result is an impressively fast and responsive vacuum build coupled with excellent precision in true flow control. Intelligent valve technology will undoubtedly enable surgeons to conduct safer and more effective surgery. ■

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