SPOTLIGHT feature

Pumps, Valves & Liquid Handling

The Increasing use of Syringe Pumps

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Syringe pumps represent a very special case in the broad family of metering pumps. They are the result of highly developed, modern mechanical engineering, that now makes it possible to manufacture exceptionally high-precision gears, as well as of control technology based on specific computer software. Their task is to transport fluids of differing viscosities continuously and in precise volumes. It all started 65 years ago with a simple infusion device designed by Dr Hess which possessed only a primitive gearing (*Figure 1*). Modern syringe pumps bear very little relation to this original device. The transportation of fluids, which in the vast majority of cases is continuous in nature, is still accomplished using peristaltic infusion pumps equipped with slide members. Although these make it possible to achieve a constant flow with low pulsation, the actual volume transported is only as precise as the volume of the tubing that is compressed by the rotation of the shaft. By contrast, in syringe pumps, the continuous flow rate is limited by the flow rate of the syringe itself (1-50 mL). The main task of such pumps is the precise, constant metering of small volumes.

Structure of Syringe Pumps

Although modern syringe pumps may have differing designs depending on their area of application, they all nevertheless contain the same basic components: the syringe holder, the threaded spindle that drives the syringe plunger, and a control program. In most cases, the spindle drive makes it possible to transport a continuous volume at a tolerance that is often given as + 2%. The fluid volume that is actually transported depends on the predefined drive speed as well as on the volume of the syringe. The decisive factor is therefore the distance the syringe plunger has to travel in a given time in order to achieve the desired fluid flow with the employed syringe volume. Absolute volume control is achieved through the principle of direct displacement. It is not necessary to calibrate the pump because the precision of the flow speed is always equally high.

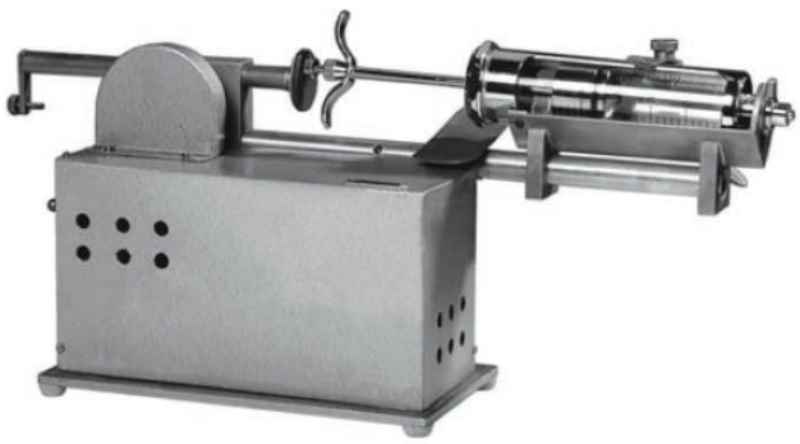

Figure 1. A simple infusion device designed by Dr Hess possessing primitive gearing

In modern pumps, it is possible to select and adjust numerous parameters. In principle, syringe pumps can also be used in suction mode. It is important to note that the transported media are never in contact with the mechanical pump components. Instead they are located in the closed syringe system (*Figure 2* Adjustable syringe holder in the SYMAX pump). The differently sized syringes are easy to exchange, with the result that the syringe pump can be used for a variety of applications. There are also devices that permit multiple arrangements of up to 10 syringe pumps. Alongside the high-precision pumps, it is also necessary to mention the high-pressure syringe pumps that can be used in all technical applications where pulsation-free, precise metering of specific transported media is required, including, for example, high-viscosity solutions. A distinction is made between medium-pressure pumps that are used to introduce viscous fluids into systems at the appropriate pressure (up to 200 bar), high-pressure pumps (up to 510 bar) and, finally, ultra-high-pressure pumps (up to 890 bar).

However, syringe pumps may not be used for human medical applications without appropriate authorisation. Infusion syringe pumps in which the syringe is adapted to the pump design and which operate at infusion rates of, generally, between 0.01 mL/h and 200 mL/h, are authorised for such applications. The output options (e.g. mL/h) can be chosen freely. It is also possible to make use of various alarm functions, for example for the detection of air bubbles in the case of infusion pumps. Due to the need for a power supply, it may sometimes be necessary to operate pumps using a rechargeable battery if the entire apparatus has to be mobile.

Recently, low-pressure syringe pumps that permit the high-precision transportation of even extremely small volumes of 0.005 µL/h have become available.

Application Fields for Syringe Pumps

Syringe pumps are now used in many other applications and in particular wherever precise metering is required.

Modern syringe pumps are also used in the field of medical and pharmaceutical research. They are of particular value whenever volumes in the µL range have to be precisely dispensed, for example in order to add tiny concentrations of an active ingredient or mix very small quantities of reagents during experiments.

As examples of typical applications, manufacturers of syringe pumps list, for example, the intravenous administration of products in animal experiments, the dispensing of adhesives, use in filling systems or, more generally, all types of mixing process. For biological research purposes, the Ruhr University in Bochum has developed an electrochemical robotic system for the implementation of electroanalytical methods on microliter plates and biological assays and, more generally, for the investigation of biological questions that also involve the use of syringe pumps.

It is also known that syringe pumps, and in particular those that operate at high pressure, are also used to transport chemicals, for feeding reactors or in the field of catalysis. The requirements are always precision and the provision of a stable, pulse-free flow. High-

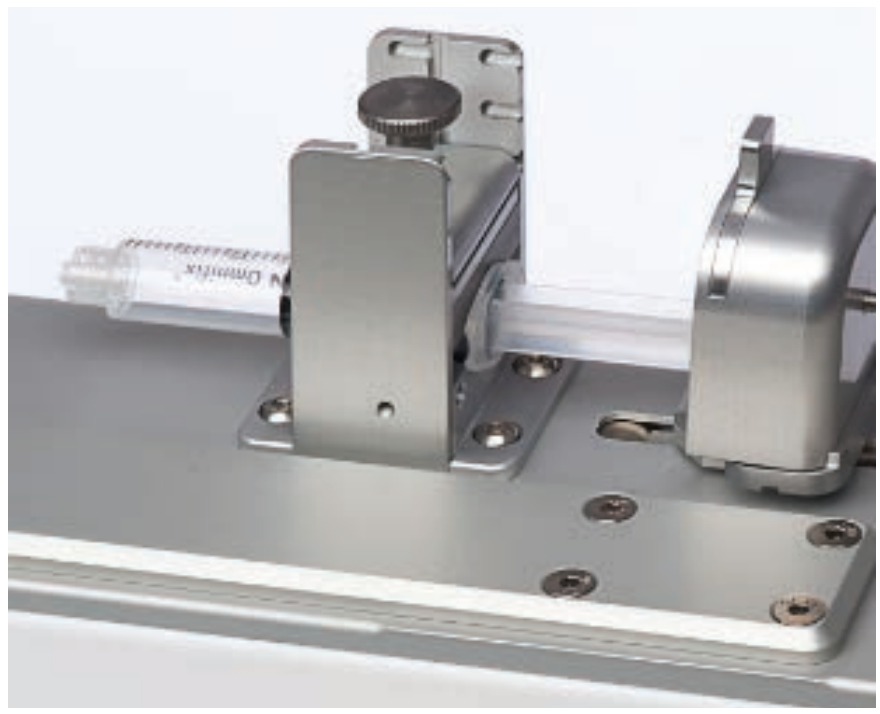

Figure 2. Adjustable syringe holder in the SYMAX pump

pressure, high-temperature syringe pumps – i.e. pumps equipped with a heatable syringe – that can achieve low flow rates are suitable for use in core flooding experiments.

It is now also possible to use gastight syringes to perform specific micro-vaporisation operations, for example in the field of microchip fabrication.

The use of syringe pumps that are able to transport exceptionally small fluid flows in the nL range is growing greatly. In the fields of microfluidics (behaviour of fluids in very small spaces), flow chemistry (reactions in continuously flowing fluids) and microreaction technology, the freedom from pulsation of the generated fluid flows is extremely important.

In instrumental analytics, syringe pumps are used for the implementation of chromatographic methods in the fields of HPLC (High Performance Liquid Chromatography) and LC-MS (Liquid Chromatography/Mass Spectrometry) in order to minimise background noise during electrochemical detection through the high-precision, stable transportation of the mobile phase.

Finally, it is also necessary to consider one other extremely important area of application. When conducting analytical examinations of very small concentrations, it does not make sense to produce the stock solutions required for calibration using normal dilution methods. In such cases, syringe pumps that are able to dispense very small volumes (µL or nL) of solutions with known, analytically controlled proportions of elements to a high level of precision are extremely suitable. This should finally make it possible to develop reference processes for use in specialist areas of nanotechnology or in the field of the life sciences.

The new Syringe Pump from Spetec

To make the advantages of using syringe pumps clear once more, let us describe the SYMAX syringe pump (*Figure 3*) in more detail here.

The SYMAX syringe pump was designed to meter different fluids in the microliter and nanolitre range. The mechanical highlights are the gearless stepper motor for the carriage drive, the high-precision carriage itself, the adjustable syringe holder (see *Figure 2*) and the resulting possibility of replacing syringes. The extremely high resolution of 25,600 individual steps per revolution makes each step imperceptible while simultaneously guaranteeing the transportation of exactly 4 pL per pulse when using a standard syringe. Depending on the volume of the employed syringe, the total amount delivered is between 0.5 nL and 44 mL per minute. Both disposable and metal-free precision syringes can

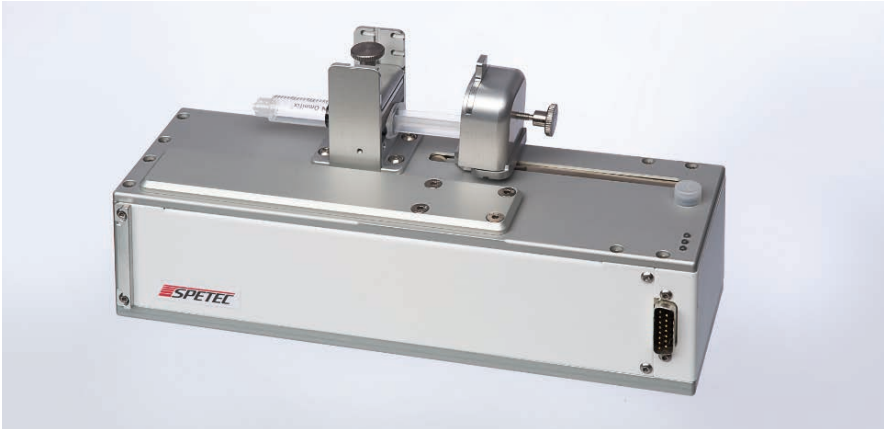

Figure 3. The SYMAX syringe pump

be used in the adjustable holder as required. If it is necessary to dispense a number of different fluids, it is possible to operate up to six units at a single USB interface and this number can be doubled as an option. An individual unit or the entire system can be configured from a PC.

Using a software-controlled 3-way valve for switching between metering and filling or suction mode, it is possible to refill the syringe without having to remove it from the adjustable holder. Metering operation can also be started using a foot switch so that the operator always has both hands free.

Thanks to the software, the SYMAX syringe pump is even more versatile in use. One basic functionality is the individualised adaptation of the flow during metering and filling. In addition, it is possible to set the unit for continuous fluid delivery over a given period or specify the minimum transport volume per individual step. This also applies to the automatic repeat cycles, rest times, emptying and filling level of the syringe and the control of the solenoid valve.

The software and firmware can be updated via the Internet. The SYMAX syringe pump is a state-of-the-art device that permits a wide range of applications in the research and development fields as well as in industrial practice.