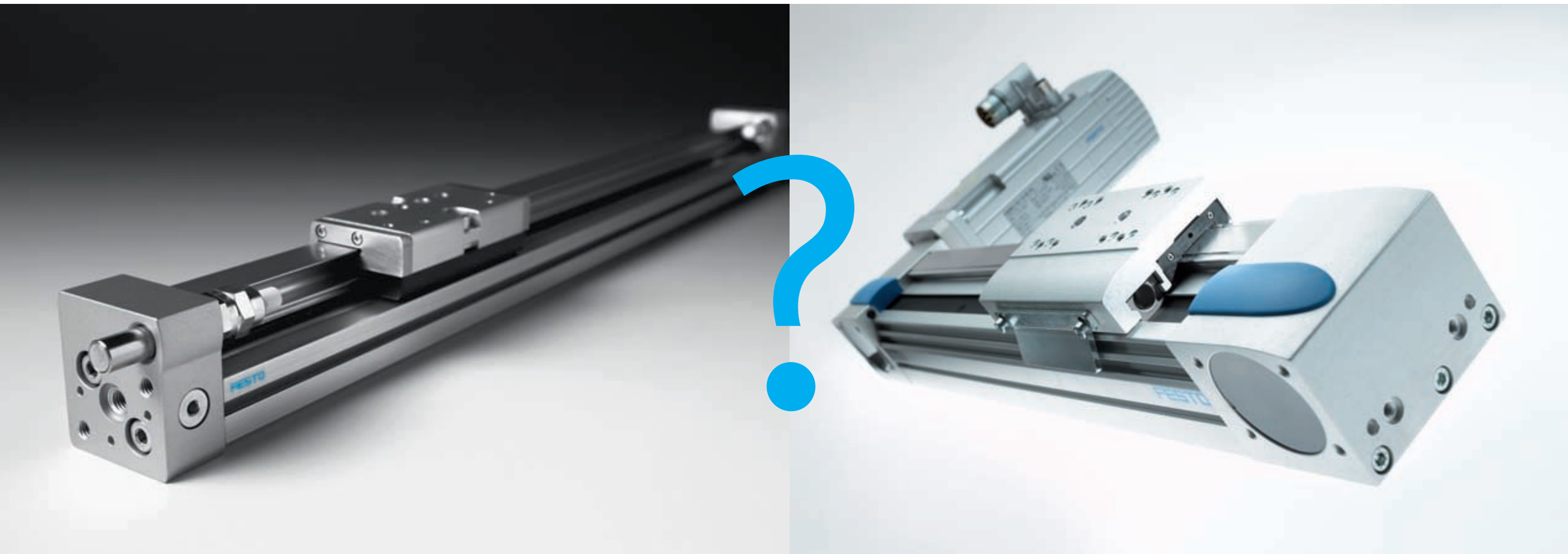
White Paper

Selecting the Optimum Motion Control Solution for the Application

FESTO



The machine with the optimum motion control will help the end user improve the bottom line through labor reduction, higher throughput, and faster return on investment. Motion control that is easy to use and set up, straightforward to troubleshoot, and backed by a quality support team adds to the advantages of the physical solution.

July 2010

By: **Joseph Biondo**
Electronic Business Development Manager,
Festo North America
Joseph.Biondo@us.festo.com

Selecting the Optimum Motion Control Solution for the Application

By Joseph Biondo, Electronic Business Development Manager,
Festo North America

The successful machine builder develops products that offer superior price, performance, reliability, and the ability for their customers to lower direct labor costs. The machine builder's reputation for quality and support also influences a buyer's decision, as does the total cost of ownership.

The majority of machine builders today incorporate into their machines off-the-shelf control components such as PLCs, HMI, and I/O. These components and systems offer the best price/performance ratio in the industry's history. The same price/performance advantages apply to motion control technology for both pneumatic and electric powered motion. Motion control is far more complex, however, compared to discrete control. Selecting the correct motion control component or system for the application is not simply a matter of counting I/O and sizing the controller to match. The choice involves mechanics, the physics of speed and acceleration, and the electronics of precision control.

Each motion control application is a mix of considerations. For example, the back and forth repetitive motion of a cutting knife requires a far simpler and less expensive solution than the complex multi-axis movement of delicate silicon wafers.

In terms of motion control, machine builders can use air pressure — pneumatics — or electrical energy to drive the motion of mechanical actuators. One machine may be based on pneumatic motion, electric motion, or a combination of both. The electrically-powered motion control market is growing faster than that of pneumatics because the price/performance ratio of electrically driven motion control has improved dramatically. The human perception that electronics can meet every need also plays a role.

Even with the bias toward electric powered motion control, it is important to understand that both pneumatic and electric powered mechanical motion offer a sweet spot in terms of applications. Pneumatic and electric powered motion control forms an application continuum from lower to higher cost and from lower to higher precision. Knowing where, when, and why to apply one form over the other gives the MACHINE BUILDER, and ultimately the end user, the greatest potential for optimum productivity and lowest total cost of ownership.

Where, when, and why to apply pneumatic motion control

Basic pneumatic control is typically 30 to 50 percent lower in cost than an electric motor solution for the same application. Pneumatics offers a reliable motion for simple in/out, up/down, and rotary applications requiring high-force and high-speed continuous motion.

With the typical standard pneumatically controlled actuators there is no mid-point positioning. These were previously referred to as “bang-bang” actuators because they slammed into shock absorbers to stop. Today various forms of cushioning can be used to slow the actuator as it comes to the end position, creating a softer stop.

Pneumatic actuators typically have a small footprint on the machine, a real advantage when space is at a premium. Pneumatic systems are easy to set up and maintain. Typical applications include flying knives for cutting, inserting press-fit components, or rejecting non-conforming parts.

Figure 1: A typical rod-style pneumatic actuator

In some manufacturing plants with hazardous environments, where sparking may be a safety issue, pneumatics are preferred. For example, in Class 1 Division 1 settings pneumatics may be the only motion control solution allowed under the National Electric Code. Festo, for example, has worked with customers in Class 1 Division 1 environments where fully pneumatic solutions were employed in the packaging of extremely fine powders and flammable household cleaners.

The myth that standard pneumatic motion control wastes energy comes from the reality that leaks in pneumatic lines can occur in improperly maintained systems. Festo has the capability, for example, of analyzing pneumatic systems to help ensure optimum energy usage.

Servo pneumatics
While standard pneumatically powered actuators are not designed for mid-stroke positioning or controlled velocity, servo pneumatic actuators, which have been on the market for a decade or more, offer infinite positioning. These closed loop actuators have proportional valves that can control the positioning of the cylinder's piston. Servo pneumatic systems began with analog signals. Today's most advanced systems feature multi-bit digitally controlled valves. This precise control allows these systems to perform up to 30 percent more cycles per minute than standard pneumatic actuators.

Servo pneumatics offer:

- High power
- A small form factor
- Closed loop control

Like all pneumatic systems, servo pneumatics are suitable for high speed, 24/7 duty cycles. For example, servo pneumatic motion control is ideal for a manufacturing line where various sizes of product are being shuttled or for lines where heavy packages up to 150 pounds (68 kg) have to be shuttled at high speed.

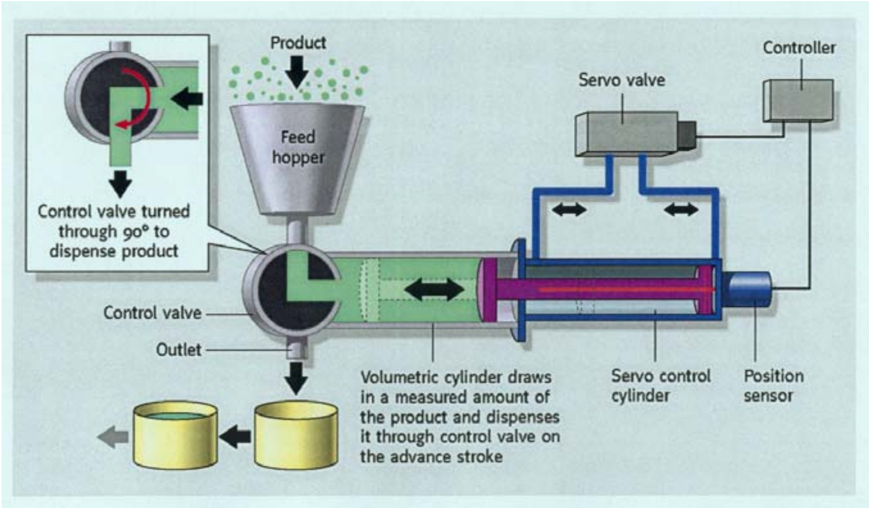


Figure 2: Servo-pneumatics are ideal when closed-loop control and large forces are combined, like in this volumetric filling application

The table below presents a comparison of standard and servo pneumatic systems.

Drive technology	**Standard Pneumatics**	**Servo Pneumatics**
Load	Up to 220 lb (100 kg)	Up to 660 lb (300 kg)
Stroke	Up to 28 ft (8.5 m)	Up to 7 ft (2 m)
Velocity	9 ft/s (3 m/s)	20 ft/s (6 m/s)
Acceleration	98 ft/s^2 (30 m/s^2)	98 ft/s^2 (30 m/s^2)
Precision	.004 in (100 µm)	.008 in (200 µm)
Noise	Very noisy	Noisy
Stiffness	Medium	Low
Flexibility	Hard stops only	Infinite positions
Typical Costs	1	1.5-2X standard pneumatics

Table 1: Comparison of standard and servo pneumatic systems

Stepper motors — moving out of pneumatics and into electrically-driven motion control

A stepper motor is a permanent-magnet motor that moves in increments. Basic stepper motors do not require position feedback. They are typically the lowest cost electric power technology available for motion control and offer ease of use and low maintenance. More advanced stepper motor systems offer full closed-loop servo control. Stepper motors are ideal for high torque, low speed — less than 2,000 rpm — intermittent duty applications. Small increments of movement call for a micro-step motor.

Stepper motors are often used when short, repetitive movements are needed — indexing, for example. In one application, a stepper motor moves a welding gun to transverse door hinges — welding the hinges to a frame. The 5 lb (2.2 kg) gun was moved at 2 ft /s (0.6 m/s) and was controlled by a touch screen operator interface panel.

Figure 3: Pick-and-Place systems with toothed-belt actuators are ideal applications for stepper motors and drives

Toothed-belt actuators are ideally matched to the stepper system. The combination of the relatively low speed of the stepper, with the high amount of linear motion per rotation of the toothed-belt pulley, give a good price/performance ratio, as long as the weight is not excessive and the accuracy is not critical.

Servo motors and mechanical drives

The fastest growing segment of the motion control industry is intelligent digital servo amplifier/motors principally because servo motors coupled to the optimum actuator for the application deliver precise and highly-repeatable motion control.

Electric servo motors are recognized for the ability to boost productivity and lower direct labor costs. In the past, machine changeover between different sized products required skilled workers to make mechanical adjustments to the machine. The process took time and directly impacted throughput. Today precise changeover adjustments can be made automatically through servo control. Servo motor control spans a wide range of costs and applications.

The simplest control, the one axis servo motor, overlaps stepper motors in terms of cost and functionality. Multi-axis precise applications calling for high acceleration increase the cost of the system. Electric servo solutions are at the top end of precision when used with high-resolution feedback. For example, wafer handling at a fabrication facility calls for this type of precise motion control. Festo worked with one customer on a high-speed cutting application at a plant manufacturing concrete siding panels. That application called for precision, speed, and high reliability.

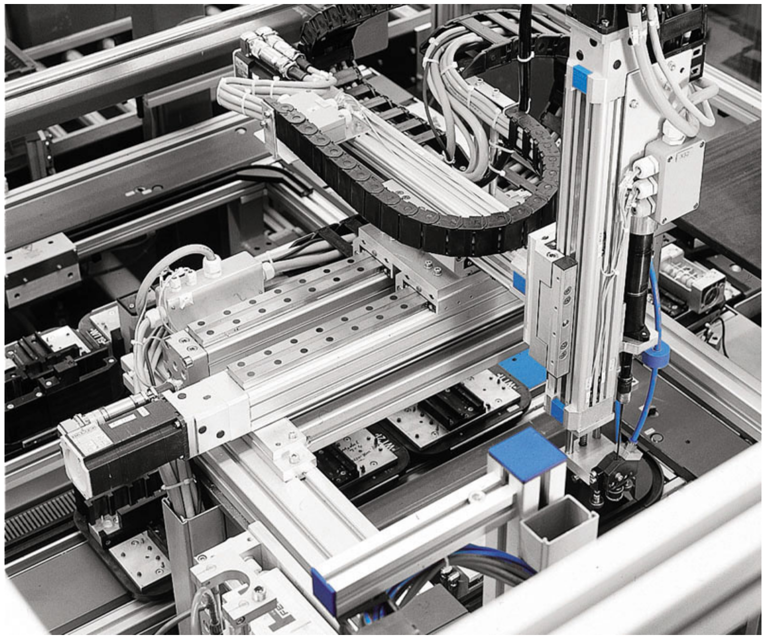


Figure 4: Electric Servo Systems are ideal where high precision is required

The following chart describes the key parameters of servo motors connected to mechanical drives.

Mechanical Drive Technology	**Belt Driven Axis**	**Lead Screw Driven Axis**	**Ball Screw Driven Axis**	**Linear Motor Axis**
Load	Up to 440 lb (200kg)	Up to 220 lb (100kg)	Up to 440 lb (200kg)	Up to 66 lb (30kg)
Stroke	Up to 33 ft (10m)	Up to 6.5 ft (2m)	Up to 6.5 ft (2m)	Up to 33 ft (10m)
Velocity	16-32 ft/s (5…10m/s)	1.6 ft/s (0.5m/s)	10 -16 ft/s (3…5m/s)	16-32 ft/s (5…10m/s)
Acceleration	328 ft/ s^2 (100m/s^2)	98 ft./ s^2 (30m/s^2)	164 ft/ s^2 (50m/s^2)	492 ft/ s^2 (150m/s^2)
Precision	.004 in (100µm)	.002 in (50µm)	.0008 in (20µm)	.00012 in (3µm)
Noise	Noisy	Low	Medium	Low
Stiffness	Medium	Very high	High	High
Typical cost	1.5 to 2X standard pneumatics	2 to 3X standard pneumatics	2 to 3X standard pneumatics	3 to 5X standard pneumatics

Table 2: Comparison of Actuator Technologies Combined with an Electric Servo System

This chart summarizes some of the key strengths of the various pneumatic and electric options described in this article.

Drive → Technology: **Application with:↓**	**Standard pneumatics**	**Servo pneumatics**	**Belt drive axis w/ stepper**	**Belt drive axis w/ servo**	**Ball screw axis w/servo**	**Linear motor axis**
High load		✓		✓	✓	
Long stroke	✓		✓	✓		✓
High velocity			✓	✓		✓
High acceleration				✓		✓
High precision					✓	✓
Low noise					✓	✓
High stiffness				✓	✓	✓
Low cost	✓	✓	✓			
Multiple positions		✓	✓	✓	✓	✓

Table 3: Application Strengths of Various Motor/Actuator Combinations

Finding the right supplier

While motion products from different suppliers all roughly perform the same functions, a wide variation exists in terms of set up, ease of use, reliability, troubleshooting, and the ability of the supplier to provide software and firmware upgrades. The selection of the motion control vendor definitely has an impact on overall performance of the machine and the satisfaction of the end-user customer.

In determining the correct motion control solution, not only is it important to consider the motive force — pneumatic power or electrical power, but also how that force integrates with the actuator technology rods, belts, screws, ball screws, or linear motors. As the charts on pneumatics and electronics show, each actuator technology offers different “sweet spots” in terms of load, stroke, velocity, acceleration, noise, stiffness, cost, and flexibility. The soft issues such as ease of use, set up, and support are also factors. The supplier of the motion components or systems must be proficient in the mechanics and electronics of motion.

Some suppliers specialize in pneumatic solutions, while others focus solely on electric motors. Some suppliers offer motion as part of a large product offering. The problem with suppliers offering only one range of solutions —pneumatic, electric, or as an adjunct to a actuator line — is that they often can’t cover the gamut of possibilities.

Search for a supplier that will examine the machine and come back with an optimum solution — a solution that may be pneumatic, electric, or a combination of both. The ideal motion supplier will be expert in the mechanics, physics, and electronics of motion as well as a company that provides excellent customer service. This supplier’s products should be compatible with the major PLC and device level networks for a de-facto open solution.

Here is an example of a comprehensive approach to motion, one not limited to one technology or another. Festo offers a rod type actuator called the DNC in which force is developed via compressed air. The DNC has adjustable cushioning that allows for a reduction in piston velocity. The DNC pneumatic actuator also has a mounting for a magnetic switch that provides a positive indication of the cylinder piston reaching its end stroke positions. Festo's DNCI replaces standard pneumatics with servo pneumatics for low cost infinite position control of the actuator. The DNCE actuator is a rod actuator that is driven via ball screw or lead screw connected to a stepper motor or an AC servo. The DNC-LAS is a linear AC servo. Each of these motion solutions, DNC, DNCI, DNCE, and DNC-LAS, offer the same form factor but different capabilities, performance, and price points. The DNC family illustrates an approach to motion control that can meet a machine builder's needs for flexibility to apply the optimum price/performance motion control solution across a spectrum of machines, price ranges, and application, while maintaining the same actuator form factor for each machine.

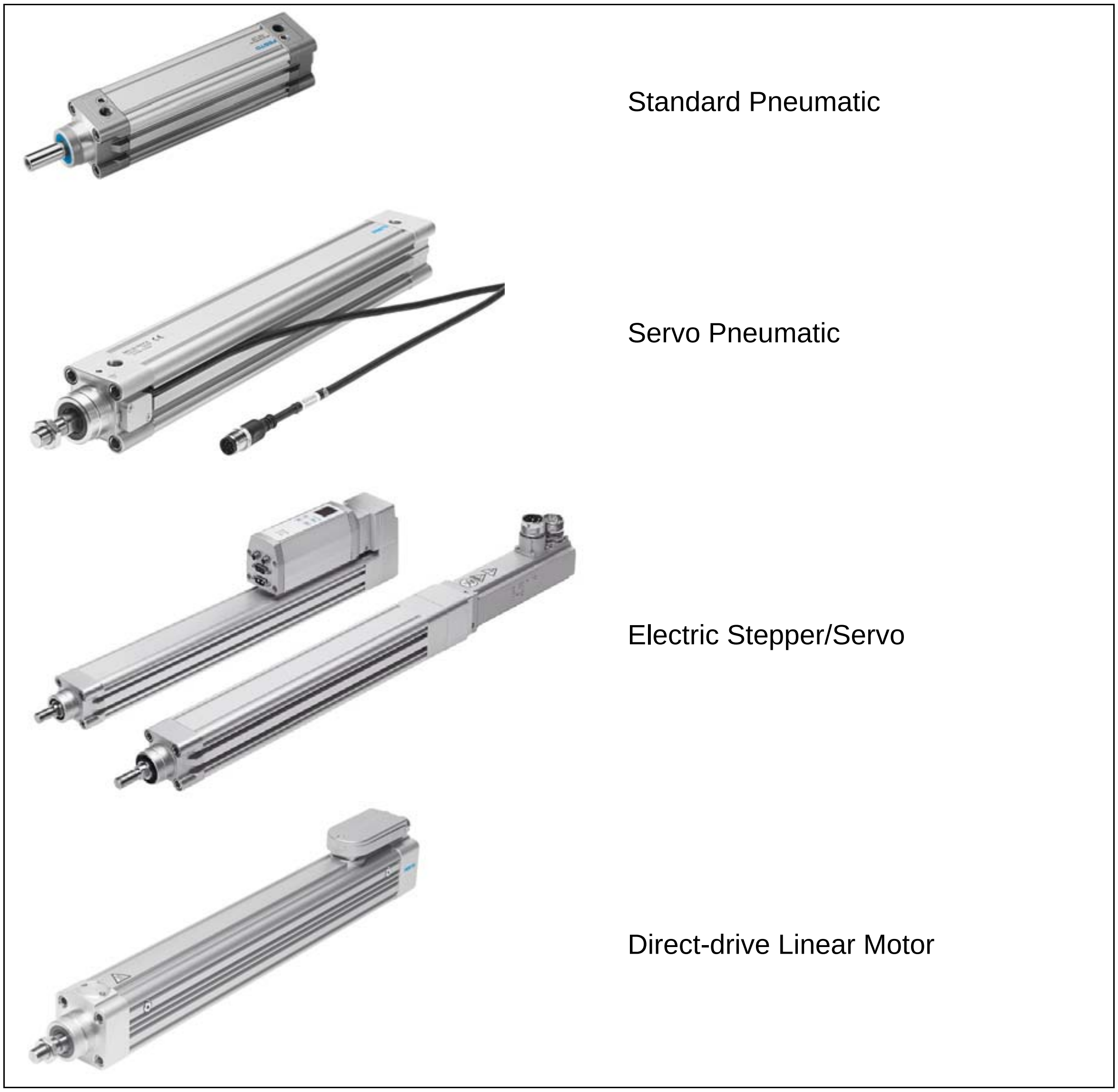


Figure 5: The same actuator style can have different drive technology

Motion control applied correctly has the power to differentiate the MACHINE BUILDER's product offering and contain costs. The machine with the optimum motion control will help the end user improve the bottom line through labor reduction, higher throughput, and faster return on investment. Motion control that is easy to use and set up, straightforward to troubleshoot, and backed by a quality support team adds to the advantages of the physical solution.

###

For more information about comprehensive motion solutions:

Festo Corporation
395 Moreland Road
Hauppauge, NY 11788
631-435-0800
631-435-8026
www.festo.com/usa

Festo North America

Festo Regional Contact Center

5300 Explorer Drive
Mississauga, Ontario L4W 5G4
Canada

USA Customers:

For ordering assistance,
Call: 1.800.99.FESTO (1.800.993.3786)
Fax: 1.800.96.FESTO (1.800.963.3786)
Email: customer.service@us.festo.com

For technical support,
Call: 1.866.GO.FESTO (1.866.463.3786)
Fax: 1.800.96.FESTO (1.800.963.3786)
Email: product.support@us.festo.com

Canadian Customers:

Call: 1.877.GO.FESTO (1.877.463.3786)
Fax: 1.877.FX.FESTO (1.877.393.3786)
Email: festo.canada@ca.festo.com

USA Headquarters

Festo Corporation
395 Moreland Road
P.O. Box 18023
Hauppauge, NY 11788, USA
www.festo.com/us

USA Sales Offices

Appleton
North 922 Tower View Drive, Suite N
Greenville, WI 54942, USA

Boston
120 Presidential Way, Suite 330
Woburn, MA 01801, USA

Chicago
1441 East Business Center Drive
Mt. Prospect, IL 60056, USA

Dallas
1825 Lakeway Drive, Suite 600
Lewisville, TX 75057, USA

Detroit – Automotive Engineering Center
2601 Cambridge Court, Suite 320
Auburn Hills, MI 48326, USA

New York
395 Moreland Road
Hauppauge, NY 11788, USA

Silicon Valley
4935 Southfront Road, Suite F
Livermore, CA 94550, USA

United States

USA Headquarters, East: Festo Corp., 395 Moreland Road, Hauppauge, NY 11788
Phone: 1.631.435.0800; Fax: 1.631.435.8026;
Email: info@festo-usa.com **www.festo.com/us**

Canada

Headquarters: Festo Inc., 5300 Explorer Drive, Mississauga, Ontario L4W 5G4
Phone: 1.905.624.9000; Fax: 1.905.624.9001;
Email: festo.canada@ca.festo.com **www.festo.ca**

Mexico

Headquarters: Festo Pneumatic, S.A., Av. Ceylán 3, Col. Tequesquinahuac,
54020 Tlalnepantla, Edo. de México
Phone: 011 52 [55] 53 21 66 00; Fax: 011 52 [55] 53 21 66 65;
Email: festo.mexico@mx.festo.com **www.festo.com/mx**

Central USA
Festo Corporation
1441 East Business
Center Drive
Mt. Prospect, IL 60056, USA
Phone: 1.847.759.2600
Fax: 1.847.768.9480

Western USA
Festo Corporation
4935 Southfront Road,
Suite F
Livermore, CA 94550, USA
Phone: 1.925.371.1099
Fax: 1.925.245.1286

Festo Worldwide

Argentina Australia Austria Belarus Belgium Brazil Bulgaria Canada Chile China Colombia Croatia Czech Republic Denmark Estonia Finland France Germany Great Britain Greece Hong Kong Hungary India Indonesia Iran Ireland Israel Italy Japan Latvia Lithuania Malaysia Mexico Netherlands New Zealand Norway Peru Philippines Poland Romania Russia Serbia Singapore Slovakia Slovenia South Africa South Korea Spain Sweden Switzerland Taiwan Thailand Turkey Ukraine United States Venezuela

www.festo.com