Platform of valve positioners for worldwide usage

By T. Karte and K.-B. Schärtner

A multitude of requirements is placed on positioners depending on the application and site of operation. Even though it is not possible to incorporate all the requirements in one positioner model, a positioner platform can still provide the major features common in all positioner models. In particular, users active on the global marketplace, for example engineering companies or manufacturers operating a worldwide network of production plants, find ways to save costs where positioners are concerned by purchasing standardized products with uniform design and performance with regards to control properties, standard mounting arrangements, availability of all types of approvals for use in hazardous areas and certifications for all major regions, user-friendliness as well as simple operation.

The important aspect of using field-proven equipment can only be accomplished by using standardized instrumentation. Staff training, familiarity with the instruments used as well as documentation on the control accuracy and reliability achieved are among the requirements stipulated by the IEC 61511 standard that are decisive for safe plant operation.

The following article discusses the requirements placed on positioners in modern plants worldwide and the different ways of implementing them.

The growing automation of industrial process plants has led to control valves with manual operation being replaced by valves moved by pneumatic actuators, allowing for remote operation. The standardized pneumatic signal of 0.2 bar to 1 bar was used to transmit signals between the control station and the control valve, and at the same time provided the necessary supply air to operate the actuator. Growing requirements on process control accuracy and thus on the control valve's positioning accuracy led to the introduction of cascade control. A positioner attached to a control valve in the field transforms a set point transmitted as a pressure signal into the corresponding position of the valve stem directly at the control valve.

Figure 1 shows such a positioner, manufactured from around 1953 to 1964. The set point and the actually measured value are converted into forces by a tension strap and bellows; the deflection resulting from comparing the forces controls the pneumatic booster that provides the supply air for the pneumatic actuator. This simple principle of operation (**Figure 2**) is reflected in the similarly simple design of the positioner as shown in Fig. 1. Positioners of this kind can still be found in old plants, where they reliably do what they are expected to do.

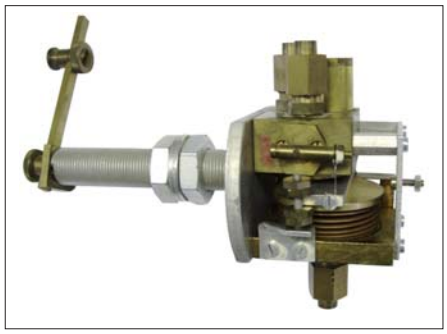

Fig. 1: Pneumatic positioner approx. 1950

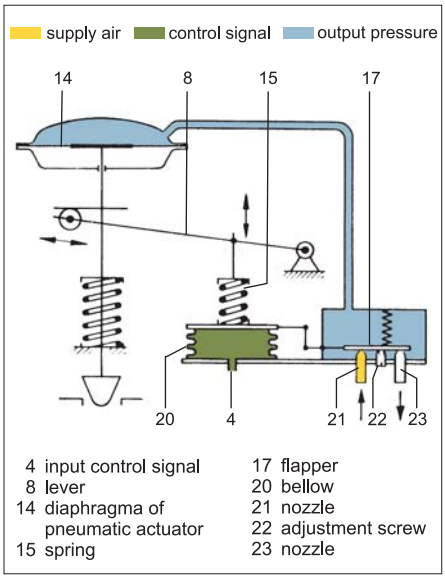

Fig. 2: Principal design of type 703 positioner

Industrial automation in the early 21st century is characterized by catchy words like life cycle cost, asset management, networking, and communications technology. As a result, field units, particularly the latest-generation positioners, are all equipped with microprocessors, provide a multitude of setting options in the form of parameters, record status data in the field, generate diagnostic alarms from the collected data as well as offer various methods of communicating with the control station. Depending on the type and place of application, the desired type of explosion protection, and specific diagnostic capabilities, operators need to choose the appropriate positioner from the wide variety of devices available on the market. But, can operators really find what they need in view of the different concepts and designs? Apart from providing numerous electronic add-on features, do all models really focus on fulfilling the core requirements, i.e. providing:

- ▷ High control accuracy,
- ▷ Ruggedness and reliable operation under all ambient and process conditions,
- ▷ Simple operation?

A possible solution is presented in the following sections. The series of modular valve positioners, which excellently fulfil the core requirements, is designed for use all across the world and in all kinds of applications.

Control concept

Diagnostics as well as communication and parameterization capabilities are a must. They make it indispensable to

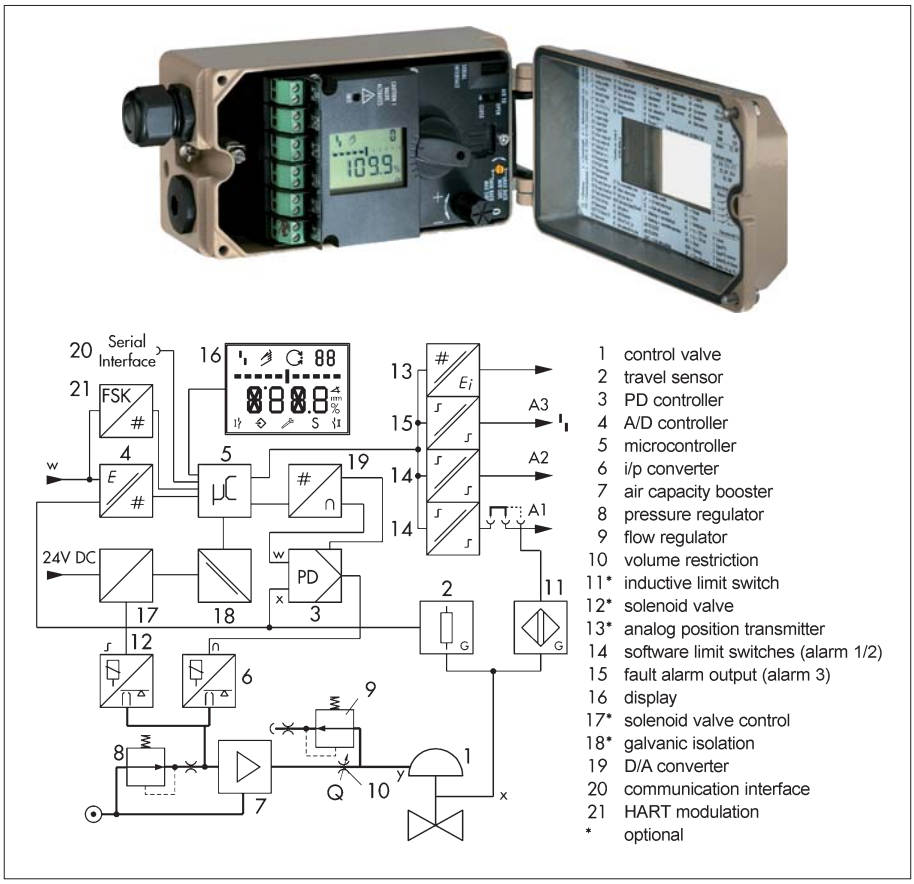

Fig. 3: Principal design of type 3730-3 positioner

include microprocessors in field equipment. However, when using such digital positioners, the microprocessors' sequential processing and thus the cycle time for processing the control algorithm turn out to be major drawbacks. When there is a need for rapid control and particularly when sudden changes of the disturbance variables occur, for example when varying forces act on the valve plug, a positioner as shown in Figure 1 is superior to some modern positioners.

These drawbacks can be avoided by using a control approach based purely on analog components. The Series 3730 Positioners from SAMSON are designed to take this into consideration. Optimum solutions were found for the three basic types of components included in a positioner: electronics, pneumatics, and travel sensing:

- Electronics (**Figure 3**): A classic operational amplifier compares set point and actual value. As a result, countermeasures can be taken immediately when disturbance variables occur. All parameters can be set thanks to the microprocessor, which acts on digital potentiometers. Thus, the dynamic response of these potentiometers has no effect on control accuracy.
- Travel sensing components: A potentiometric setup is specially adapted to the task at hand (**Figure 4**). The valve position is transmitted to the positioner over a rotary shaft. This shaft moves the slider of the potentiometer over a fixed lever and without using any gearing. The 60 mm sliding track for the potentiometer is exceptionally large.
  This design has proven its ruggedness and reliability over many years in several tens of thousands of positioners even under the most adverse operating conditions. The measuring accuracy achieved is several times higher than the positioning accuracy required for the valve. This excess accuracy not only improves diagnostics and control accuracy, it also contributes to the simple setting of the positioner. The mechanical attachment allows the positioner to move through only 20 % of the maximum travel without requiring further mechanical adjustment as the electronics automatically adapt the travel sensing mechanism. As a result, mechanical attachment and start-up are simplified considerably.
- Pneumatics: Analog components are used throughout as well: A classic flapper/nozzle system acts on a booster. The entire system has a well-defined characteristic, with the i/p converter's input current being proportional to the output pressure. Pressure regulation provides more precise control results compared to systems that only control the flow rate or are pulse controlled. Disturbance variables, such as leakages in the downstream pneumatic actuator, are balanced out without producing a system deviation or oscillations.

The achieved control accuracy is described in [1] and [2]. In addition, the ruggedness is to be highlighted. In a temperature range between -40 °C and +85 °C and for oscillation forces up to 4g, a superior reliability is reached even when the devices are in operation for several years. A fundamental contribution to this extraordinary reliability is made by the chosen housings: Aluminum housings are used for all positioner types. Apart from mechanical stability, an outlet filter guarantees degree of protection IP 66. Electromagnetic compatibility in accordance with EN 61000-6-2 and EN 61000-6-3 as well as NAMUR recommendation NE 21 are also complied with.

Downstream integration – attachment to the valve

Apart from the positioner used, the achieved reliability and control accuracy also depend on further factors. A key factor often overlooked is selecting the appropriate method of attachment. In addition, the chosen actuator type also influences the achieved results. As illustrated in **Figure 5**, the first distinction needs to be made between actuators with rotary and linear motion. Piston and diaphragm actuators differ in the amount of friction produced; precise control requires the lowest possible friction. Rack-and-pinion drives can additionally tend to slip.

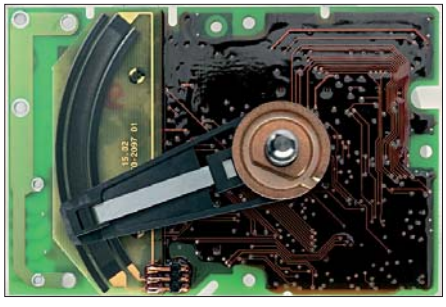

Fig. 4: Potentiometer as position sensor

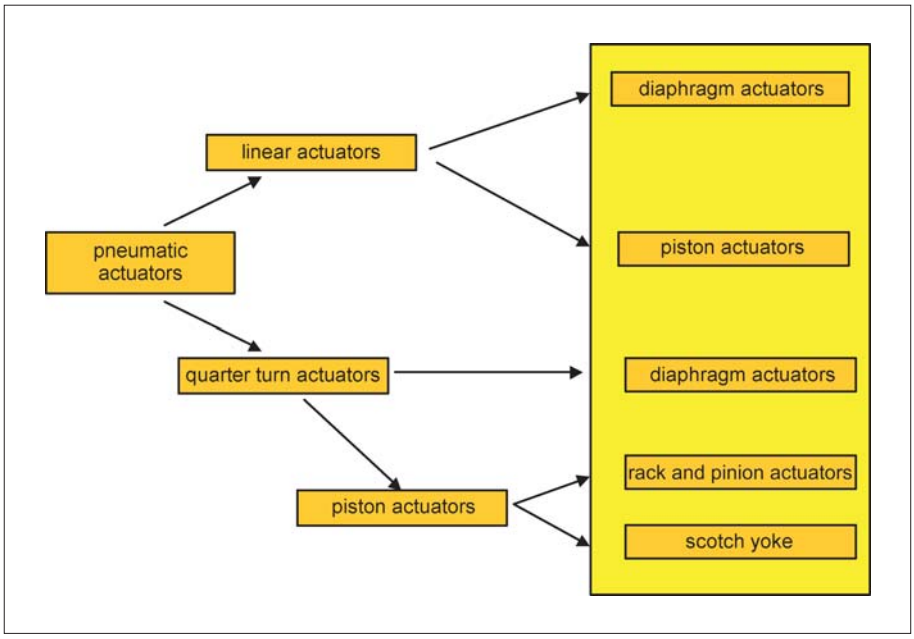

Fig. 5: Pneumatic actuators

Fig. 7: Globe valve with positioner attached in accordance to Namur

Positioner attachment to rotary actuators is dealt with in IEC 60534-6 and VDI 3845; **Figure 6** shows a possible implementation. The shown attachment uses the standardized bore pattern, but goes much further than the standard specifications when it comes to protecting the moving parts. Protecting the moving parts is particularly important for operational safety.

This aspect is even more important for linear actuators. **Figure 7** shows an attachment according to the IEC 60534-6 standard, commonly referred to as NAMUR attachment. Valves by foreign manufacturers have yet other mounting arrangements. Nevertheless, the method of transmitting the linear movement to the rotating positioner shaft is almost always similar to that depicted in Figure 7.

Fig. 6: Quarter turn actuator with valve and positioner (courtesy of Pfeiffer-Chemieearmaturen-Bau GmbH)

Analyses of failure causes on automated control valves in the field have shown that unprotected linkages or gearings are particularly susceptible to failure. A suitable countermeasure is the integral positioner attachment as shown in **Figure 8**, a manufacturer-specific, patented solution. In principle, attachment as in Figures 6 or 7 is possible on any valve, possibly requiring a mounting kit to be developed or modified.

Integral attachment as in Figure 8, however, requires the use of dedicated valve types. The advantages of integral attachment are:

- ▷ All moving parts are enclosed and thus protected from mechanical influence and damage, at the same time eliminating the risk of personal injury.
- ▷ Exhaust air scavenging (flushing the actuator's spring chamber with the positioner's exhaust air) reliably prevents contamination and corrosion by corrosive media; a compelling advantage in some production plants.
- ▷ Extremely simple mechanical attachment using only three screws and no small parts that may get dropped from the mounting platform at the decisive moment allows a positioner to be installed or replaced virtually within two minutes.
- ▷ The air is routed between the positioner and actuator through a flanged-on mounting block that requires no external piping and allows the positioner to be replaced without having to reinstall any external control lines.
- ▷ Thanks to the modular valve series with fixed travels between 5 mm and 50 mm, there is no need to mechanically adjust the positioner on the valve. A follower pin is fixed on the pick-up lever in a preset position assigned to the desired valve travel; the rest is done by the positioner's automatic self-calibration function.

Fig. 8: Globe valve with integrated mounting of positioner

Fig. 9: Pneumatic actuator with additional components

This feature helps save time and ensures better safety of the process–just imagine a remote site with insufficiently trained staff.

- ▷ The prevention of dirt accumulation and the special design of the pick-up lever result in a travel pick-up system that requires absolutely no maintenance as has been proven by quality assurance data. Effects like abrasion on the pick-up lever, breaking of the spring on the lever, and other causes of failure well known to plant operators are things of the past.

VDI 3847 attempts to dictate integrated attachment as a standardized connection interface. This solution, however, has not been accepted on the market, with higher costs, increased weight, and the larger mounting space required being possible reasons.

Depending on the required automation task, additional accessories including volume boosters, lock-up relays, supply pressure reducers, solenoid valves for quick venting, and limit switches can be used. As a result, certain installations can become rather complex (so-called *Christmas trees*, **Figure 9**).

For large actuators and large travels, these accessories need to be mounted and connected separately, with the possibility of the mounting costs exceeding the value of the mounted accessories by far. For medium and small valve sizes, connecting as many accessories fitted into one housing as possible can reduce costs as well as increase reliability. Apart from the actual positioner components (including vast diagnostic features), a basic housing can additionally hold a maximum of two limit switches (partly mechanical), a travel feedback mechanism, and even a solenoid valve separately controlled by a 24 V signal (**Figure 10**). Moreover, these integrated accessories considerably enhance the positioner's scope of functions:

- ▷ The positioner monitors the 24 V signal of the solenoid valve input. If the solenoid valve is without voltage, the positioner simultaneously switches its own pneumatic path to venting. This redundant pneumatic switch-off is particularly important for the evaluation of control valves used in safety-instrumented systems.
- ▷ The data logger included in the positioner can be triggered by the input of the solenoid valve. This allows the positioner to exactly plot the moment that the valve moved to its fail-safe position in a travel-time diagram, for example. This function is of great importance when monitoring and documenting the correct functioning of safety shut-off valves.

In brief, the described positioner series can be used with all types of actuators and valves, but it is particularly favorable to purchase a complete, automated control valve from a single supplier.

Upstream integration – the positioner as part of the automation system

The importance of the positioner as a vital automation component in a plant is underlined by the joking expression "positioner with attached control valve" common among plant designers and purchasers. The following issues need to be taken into account:

Required type of protection

Most industrial process plants are categorized according to their explosion protection requirements. Apart from planning plants for Zone 1, which was common earlier, more and more devices are used as specified for Zone 2 to cut costs. Certificates by the appropriate regional authorities are always required. Certification according to ATEX (Europe) and FM/CSA (US, Canada) are known across the world, but many more certifying bodies exist depending on the location of use. Certification by the regional organization in charge is indispensable for equipment manufacturers. The associated costs are very high. Often, it is not possible to formally transfer an ATEX approval as additional examinations and on-site tests may be required. Worldwide, important approvals include those issued by ATEX, FM, CSA, IECEx (so far only Australia and New Zealand), NEPSI (China), and TIIS (Japan), but even more certificates and requirements exist.

Communication

The old two-wire connection with 4 to 20 mA signals was commonly used across the world. Due to its simplicity and reliability, this type of connection can be seen as brilliant. In accordance with the advances in digital data processing and the plant operators' desire to manage their assets, this analog signal is supplemented by superimposing the HART® protocol for two-way digital communication. This rather complex

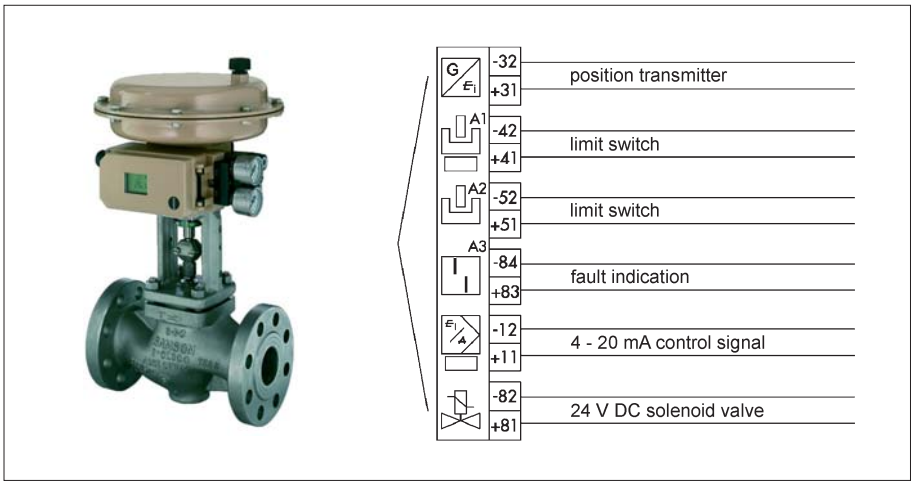

Fig. 10: Positioner with integrated additional components

protocol has been defined up to version 6, continually forcing equipment manufacturers to implement the latest version. The two important Fieldbus systems, Profibus PA and FOUNDATION Fieldbus, constantly become available in new versions and are increasingly used in process engineering.

Asset management

Device features are implemented in various ways as communication objects and structures, for example as FDT/DTM, DD (device description), or manufacturer-specific solutions like PDM (Siemens) or AMS (Emerson). The various implementations will not be dealt with here, but the incomplete list gives a hint of the immense amount of research involved. Each individual parameter option as well as each diagnostic and logging function needs to be implemented in each engineering tool and the various functions must be checked and mostly adapted after one of the frequent version updates. In any case, the objective is to provide operators with the necessary functions for their preferred asset management system.

Safety equipment

If field units are used in safety-instrumented systems, their functional safety is subject to examination. Most devices are assessed according to IEC 61508 and IEC 61511, in the US according to ISA TR84.00.02-2002. In this case, manufacturers are obliged to provide safety-related data. Operators need to make sure that the equipment is used as intended. Publications [3] and [4] contain a comprehensive presentation of possible applications for extended positioner diagnostics in safety-instrumented systems.

Universal solution for all applications: Series 3730 Positioners

The use of standardized equipment has many advantages for plant operators and planning engineers. In this case, the devices' features are well known, staff is accustomed to operating such equipment, the reliability and functional safety of the types used can be rated even in critical applications. As a result, applying standardized devices proven in use as safety equipment is favored by IEC 61511. Keeping plant availability in mind, the same approach can be taken for all other measuring and control instruments. The diverse requirements mentioned above indicate that a single device cannot fulfill all demands. The solution to this is to be found in a whole series of positioners, such as the Series 3730 (**Figure 11**).

Fig. 11: Positioner series 3730

The fundamental technical platform of all positioners in this series is identical. The main features include:

- ▷ Metal housings of aluminum in degree of protection IP 66 and NEMA 4X for all positioners. Only two versions are available: one for general applications in type of protection "intrinsically safe" and one for type of protection "explosion proof."
- ▷ Uniform mounting kit. Despite the unavoidable technical differences in housing designs for the different types of protection, the dimensions required for attachment to the control valve are identical for all positioners. This means that the same mounting parts and accessories can be used throughout.
- ▷ Identical pneumatic, electronic, and travel-sensing components. As a result, the excellent lag-free electronic control is identical in all positioners of the series as is the reliability and associated mean time between failures (MTBF).
- ▷ Integral attachment to SAMSON control valves.
- ▷ Identical operating concept for all positioners with a microprocessor, i.e. Type 3730-1 or higher. Simple operation using just one rotary pushbutton allows all parameters to be adjusted directly at the positioner without requiring a substantial manual or a computer.
- ▷ Alternatively, the positioners can be operated using a computer and the TROVIS-VIEW software for all smart positioners, i.e. Type 3730-2 or higher. The operating menu structures are identical when it comes to parameters and diagnostics. There are, however, slight differences in the communication-related functions due to the different protocols used (HART, Profibus, and FOUNDATION Fieldbus).
- ▷ Moreover, the positioners can be operated using the process control or asset management systems of all leading manufacturers. Communication is implemented using FDT/DTM, DDL, or manufacturer-specific methods.

Table 1 lists the variations between the positioners in the series. Even the basic unit, Type 3730-0, can fulfill all control tasks. Its price has been chosen to ensure that there should be no more need to use old electromechanical equipment. Despite the moderate price, the most frequently used parameters, such as direction of action, split-range operation, tight-closing function, and output pressure limitation, have been integrated into the Type 3730-0.

The next higher version, Type 3730-1, is equipped with a microprocessor and thus includes features like automatic self-calibration and selectable characteristic. As a result, this positioner cannot only be mounted on linear actuators, it is also perfectly suited for use on rotary actuators. By default, the Type 3730-1 as well as all higher versions comes with two software limit switches to indicate the valve's end positions. Communication capabilities and diagnostics are available in Type 3730-2 and higher, with

Table 1: Characteristics of different versions of positioner series 3730

type (standard/intrinsically safe) type (explosion-proof)	3730-0	3730-1	3730-2	3730-3 3731-3	3730-0 3731-4	3730-0 3731-5
attachment						
SAMSON integral	•	•	•	•	•	•
IEC 60534 (NAMUR)	•	•	•	•	•	•
rod-type yoke	•	•	•	•	•	•
rotary actuator VDE/VDE 3845		•	•	•	•	•
local operation						
DIP switches	•					
LCD and rotary pushbutton		•	•	•	•	•
standard functions						
tight-closing function	•	•	•	•	•	•
automatic start-up		•	•	•	•	•
electronic limit switches		•	•	•		
fault alarm output			•	•		
options						
inductive limit switch			•	•	•	•
valve position transmitter			•	•		
solenoid valve/forced venting			•	•	•	•
external position sensor			•	•	•	•
communication						
TROVIS-VIEW serial			•	•	•	•
HART protocol				•		
PROFIBUS PA					•	
FOUNDATION Fieldbus						•
diagnostics						
displayed locally		•	•	•	•	•
EXPERT			•	•	•	•
EXPERT +			•	•	•	•
EXPERT ++			•	•	•	•

the diagnostic functions being implemented in varying configuration stages. A detailed presentation of the implemented diagnostic functions can be found in [2].

Series 3731 EEx d Positioners

In Europe, installations in hazardous areas are mostly carried out in type of protection "intrinsically safe." Worldwide, however, the type of protection "explosion proof" is of great importance. Details on the underlying explosion-protection concepts and their regional implementations can be found in [5].

The basic idea behind type of protection "explosion proof" to safely contain any possible source of ignition inside a housing and prevent an ignition of the surrounding flammable atmosphere has led to rugged housings being used. Mechanical ducts or clearances must be extremely small.

A Series 3731 Positioner is shown in **Figure 12**. Despite the mechanical requirements placed on the housing and operating elements, the design of the positioner is compact and allows all mounting parts of the Series 3730 to be used. Special features include:

- ▷ Approvals by the important international certifying bodies (ATEX, FM/CSA, and NEPSI granted, TIIS applied for).
- ▷ Operation on site: The positioner relies on the same user interface as the Series 3730. All parameters can be set using the positioner's rotary pushbutton. Operating status and diagnostic data can be viewed on the LCD. Adjustment and display are also possible during operation, which is a particular feature of this explosion-proof device that greatly facilitates operation.
- ▷ All electrical connections are located inside a separate terminal space. As a result, the positioner can be used in ATEX type of protection EEx d as well as EEx de. The fact that the separation between the terminal space and the electronics space was classified as "factory sealed" according to FM regulations is a major advantage on the US market. This simplifies connecting conduits, without the need to use conduit seals.
- ▷ Accessories can be connected despite the compact design. The same accessories as for the Series 3730 Positioners are available. Additional optional equipment includes a digital input, which may be used for external leak sensors on the valve. A further special feature of the Series 3731 is the binary output that can supply signals according to NAMUR as well as PLC signals. **Figure 13** gives an overview of possible connections. Due to the limited space, only one option can be selected at a time.
- ▷ The communication options (local interface, HART protocol, bus connection) are basically the same as for Series 3730. The self-calibration function is identical with that of the Series 3730. The completely autonomous adjustment without requiring an operator to interact is particularly important for this type of protection.
- ▷ The overall weight is only 2.5 kg, an important aspect with respect to ease of installation under difficult conditions and resistance to vibration.

The positioner is the world's first to combine all listed features into one unit, providing simple operation and mounting as well as high control accuracy and ruggedness.

Selection criteria

As mentioned before, the described positioner series fulfils all requirements concerning

- ▷ Performance (reliability, control accuracy, operation under selected ambient conditions),
- ▷ Attachment to the desired valve,
- ▷ Integration into the control system and asset management system of choice,
- ▷ Worldwide service and support.

The SAMSON AG service and support network, in short, focuses on providing expert customer service on site through highly skilled personnel. As a result, SAMSON has established over 140 subsidiaries and offices all across the world. Each local representative is expected to do more than acquire customers and provide pre-sales service; in the interest

Fig. 12: Type 3731 Positioner

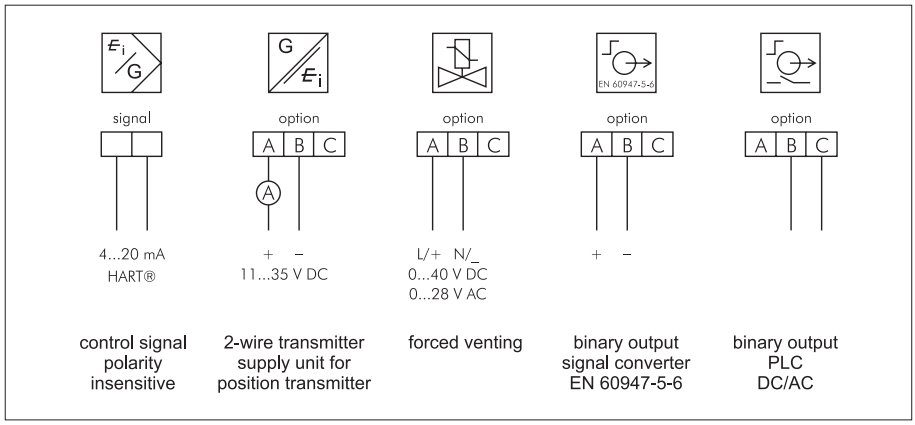

Fig. 13: Options for positioner 3731

of establishing a long-term customer-supplier relationship, all representatives need to give excellent after-sales service as well. The required staff and equipment are available on site to locally determine causes of failures and perform necessary repairs, relying on a well-equipped stock of spare parts. Customers can be given personal assistance and advice both at the local office as well as on site since difficult control valve and positioner applications are best evaluated directly in the plant. The local staff can draw on the vast expertise and experience of the team at SAMSON's Frankfurt headquarters at any time. The Frankfurt team also develops the worldwide service concept and provides multi-stage staff training for the local representatives. Moreover, an elaborate remote diagnostics scheme has been drawn up, allowing the Frankfurt specialists to assist with examining failure causes or evaluating the operating conditions.

Let us take a quick look at supplier audits as seen from the end user's perspective: It used to be common practice at large chemical sites in Germany to exclusively use typetested equipment, which guaranteed very low plant downtime. Apart from requiring exact test rig examinations and documented application during operation, this approach also demanded suppliers and operators to communicate extensively, which helped create a vast pool of data. Organizations specializing in independent evaluations of devices purely based on test rig examinations without feedback about the practical use in the field can only replace this experience in part. It may well be possible to check a Pt 100 temperature sensor after using calibrated measuring equipment and closely reading the associated standards and specialist literature. However, a positioner cannot be thoroughly evaluated without having detailed knowledge of the application and all possible operating conditions. Manufacturers cannot be expected to provide such independent evaluation organizations with fundamental knowledge. Rather, auditing a supplier the good old-fashioned way would be recommendable:

- ▷ Which technologies does the intended supplier specialize in? Which components are produced in house, which are contracted out or purchased elsewhere?
- ▷ How active is the supplier in performing positioner R&D?
- ▷ Which historic knowledge can the supplier draw on? How long has the supplier been active in the development, production, and application of positioners?
- ▷ Which quality system is in place at the supplier's? Can MTBF values at least be discussed internally and confidentially?
- ▷ How big are the chances that the supplier and its product will be available on the market in the future? Will the supplier be able to cover the necessary expenses for implementing new communication concepts and for device integration?

Outlook

Currently, the market is dominated by digital, i.e. microprocessor-based, positioners. The demand for the classic electromechanical positioners will, with few exceptions, be restricted to providing replacements for existing plants.

Where electromechanical positioners were used for cost reasons, it is now possible to install the electronic Types 3730-0 and 3730-1. They provide the same control accuracy and parameters as the Types 3730-2 to 3730-5, but they are available at a very competitive price since they have no communication capabilities.

The constantly increasing R&D expenditure on positioners suggests that the market will further consolidate. At the same time, some manufacturers will not be able to provide the required worldwide support. Apart from a large number of parameter options, modern positioners also include extended diagnostic tools both for the positioner itself as well as for the attached control valve. Currently, the manufacturers have implemented more diagnostic functions than the operators in the field actually use.

It would be desirable if operators made full use of the currently available positioner features. The close cooperation between operators and suppliers in day-to-day operation would surely open up opportunities of increasing reliability and availability as well as improving maintenance and repair schedules.

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Dr. Thomas Karte,
SAMSON AG,
Frankfurt/Main, Germany
Phone: +49 69 4009 2086,
tkarte@samson.de

Karl-Bernd Schärtner,
SAMSON AG,
Frankfurt/Main, Germany
Phone: +49 69 4009 1320,
kschaertner@samson.de