

### Application

Positioner firmware to detect potential faults in on/off valves in safety-instrumented systems and with maintenance recommendations.

## TROVIS SAFE

For on/off valves in safety-instrumented systems

The EXPERTplus valve diagnostics can detect faults and provide predictive, status-oriented maintenance recommendations for valves with pneumatic actuators. The full scope of diagnostic functions is completely integrated into the positioner. The numerous diagnostic functions allow faults to be pinpointed in control valves and on/off valves in safety-instrumented systems at an early stage. Functions include, for example, partial stroke testing and data logging.

The TROVIS-VIEW software, which allows the user to access, read and edit the diagnosis, is easy to learn. The integration options including eDD, eEDD, FDT/DTM allow the diagnostic functions to be also used in other engineering tools. Classified status messages and the condensed state conforming to the NAMUR Recommendation NE 107 can also be read on site at the positioner display and can be issued over the fault alarm contact.

**TROVIS-VIEW:** Operator interface used to configure various SAMSON devices

**FDT:** Field device tool for the manufacturer-independent integration of field devices

**DTM:** Device type manager to describe the device and communication properties

**DD/eDD:** Device description/enhanced device description

### Special features

- Diagnosis data are constantly compiled, saved and analyzed in the positioner. Status messages are automatically generated. Test data and their analysis are saved in the positioner.
- Cyclical polling of diagnosis data, multiplexer-capable
- Statistical information (in-service monitoring) and tests (out-of-service diagnostics) pinpoint critical states before malfunctions can affect the process, allowing the user to plan predictive maintenance and service work on control and on/off valves
- Integrated partial stroke testing (PST) and full stroke testing (FST)
- Minimum and maximum temperature readings with details on how long the limits have been exceeded



**Fig. 1:** Flameproof TROVIS SAFE 3731-3 Electropneumatic Positioner

- Automatic start of diagnostic functions
- Display of service and maintenance recommendations
- Display of classified status and fault messages
- Status classification and condensed state based on NAMUR Recommendation NE 107
- Status messages and condensed state can also be read off at the positioner display or can be issued over the fault alarm contact
- Plotting of valve signature to detect faults
- Diagnostic function to pinpoint changes in friction
- Operating hours counter allows data and events to be sorted by time
- Diagnosis data, test results and analysis saved in the positioner

### Options

- Binary input, e.g. to start tests, monitor external solenoid valve, etc.

## Summary of diagnostic functions

There are two main groups of diagnostic functions available:

### Statistical information

Data are compiled, saved and analyzed by the positioner while the process is running without disrupting the process. The positioner follows the set point to position the valve. A classified status alarm or fault alarm is generated if the positioner detects an event.

### Tests

Similar to the statistical information, data are compiled, saved and analyzed by the positioner. However, in this case, the valve position is not determined by the set point, but the active test. The tests can only be started when the conditions in the plant allow it (e.g. plant shutdown or service work in the workshop). For reasons of safety, these tests, except for partial stroke testing, can only be performed in the MAN operating mode.

Table 2 shows the diagnostic functions with their test analyses.

### Application type: Control valve or on/off valve

The EXPERTplus valve diagnostics is used in combination with valves with pneumatic actuators. The positioner works using the application types, control valve or on/off valve. Both application types allow the positioner to run in either AUTO or MAN operating modes.

**Table 1:** Assignment between application type and operating mode

Operating mode	On/off valve	Control valve
AUTO	Discrete analysis of the set point The valve position (current position) in % and O/C (Open/Close) appear in alternating sequence on the display.	The positioner uses the set point to position the valve. The valve position (current position) appears in % on the display.
MAN	The positioner uses the set point given over on-site operation or over acyclic communication to position the valve.	

The discrete analysis of the set point of on/off valves (AUTO mode) allows the valve to be moved to the fail-safe position or a user-defined fixed value (e.g. 100 %) by entering the corresponding set point. In addition, the partial stroke test can be started by entering the corresponding set point w.

**Table 2:** Overview of EXPERTplus functions

Function	See section	Description
Start-up diagnostics	1.1	Positioner self-test, mechanical attachment, valve working range, initialization time, opening and closing times
Current process variables	1.2.1	Process variables: set point w, valve position x, drive signal y, set point deviation e, operating hours counter
Operating parameters	1.2.2	Number of zero calibrations and initializations, temperature, total valve travel, self-monitoring of positioner
Status messages Classification	1.2.3 3.1	Display and logging of classified status messages and condensed state
<b>Statistical information</b>		
On/off		Breakaway time, transit time, valve end position
Data logger	2.1.1	Recording and saving of set point w, valve position x, drive signal y, set point deviation e with triggering function
Valve position x histogram	2.1.3	Shifting working range, working range
Set point deviation histogram	2.1.4	Limiting the working range, inner leakage, connection positioner-valve, absolute value of max. set point deviation
Cycle counter histogram	2.1.5	External leakage, dynamic stress factor acting on packing and metal bellows
Drive signal diagram steady-state	2.1.6	Supply pressure, leakage in pneumatics
Drive signal diagram hysteresis	2.1.7	Friction, external leakage
Trend of travel end position	2.1.8	Observing end position, zero shift
<b>Tests</b>		
Drive signal diagram steady-state	2.2.1	Supply pressure, leakage in pneumatics, actuator springs
Drive signal diagram hysteresis	2.2.2	Friction, external leakage
Static characteristic	2.2.3	Dead band of the valve
Partial stroke test (PST)	2.3	Analysis of the dynamic control response: overshooting, dead time, T63, T98, rise time and settling time
Full stroke test (FST)	2.4	Overshooting, dead time, T98, rise time and settling time
<b>Status messages</b>		
Software for visualization and parameterization	3	Collected data and analysis results can be displayed in graphs.
<b>Options</b>		
Binary input	4	Logged actions of single functions and tests

# 1 EXPERTplus valve diagnostics

## 1.1 Start-up diagnostics

EXPERTplus monitors the valve during automatic initialization to ensure trouble-free start-up. During which, the opening and closing times are determined.

The diagnosis also indicates faults concerning attachment and the entire valve working range as well as hardware, data memory defects and the initialization time.

## 1.2 Process variables and operating parameters

### 1.2.1 Current process variables

EXPERTplus provides the key process variables collected by the positioner (set point  $w$ , valve position  $x$ , drive signal  $y$ , set point deviation  $e$  and temperature  $t$ ) and analyzes the diagnostic data.

### 1.2.2 Key operating parameters/status messages

To evaluate the current condition of the valve and schedule maintenance routines, EXPERTplus provides the user with a status summary. The status messages for the operating parameters listed below are time-stamped:

- Operating hours counter, distinction between positioner switched on and positioner in closed-loop operation (since the first start-up and the last initialization routine)
- Number of zero calibrations performed
- Number of initializations performed
- Display of the current temperature as well as saving of the maximum and minimum temperatures, including alarm function when a limit is exceeded
- Total valve travel, including programmable limit

### 1.2.3 Pinpointing faults and their sources

The alarm and status messages generated by EXPERTplus allow faults to be pinpointed quickly. The last 30 generated messages are saved in a FIFO memory with a time-stamp (logged by the operating hours counter).

The status messages are divided into the following categories:

- Status messages
- Operational messages
- Hardware messages
- Initialization messages
- Data memory messages
- Temperature messages
- Extended status messages
- Operational error e.g.:
  - Control loop error (excessive error, e.g. blocked actuator, insufficient supply pressure etc.)
  - Zero shift
  - Hardware
  - Data memory
  - Temperature
  - Initialization

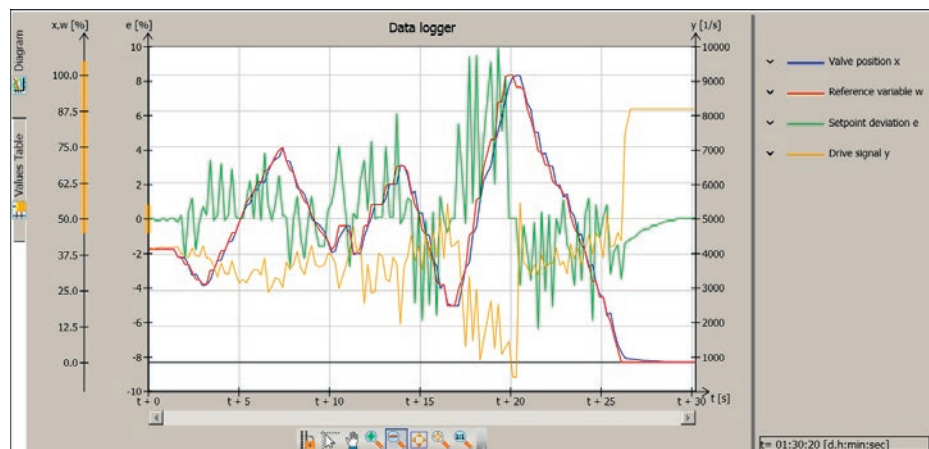


Fig. 2: Data logger

## 2 Functions

### 2.1 Statistical information

By permanently recording raw diagnostic data ( $w$ ,  $x$ ,  $y$  and  $e$ ) in the positioner, the user can gather information about how the valve behaves under process conditions.

The recording of signals enables an analysis of the current measurement span as well as of the positioner's entire service life.

The following statements can be made, for example:

- Valve positioning range OK
- Valve mainly operates in the upper or the lower end position
- Dynamic stress factor

As a result, recommendations for predictive maintenance can be given. In addition, immediately required action is reported.

#### 2.1.1 Data logger (Fig. 2)

Process variables (e.g. set point  $w$ , valve position  $x$ , drive signal  $y$ , set point deviation  $e$ , operating hours counter) are logged. The last 100 data points per variable are saved in a FIFO memory in the positioner. The time between logging data points is user-definable.

Apart from permanent sampling, the data can also be collected online while the process is running, provided a certain trigger condition is met. The trigger condition can be defined by the user as certain thresholds.

#### 2.1.2 On/off diagnosis

The on/off diagnosis provides statements on the valve end position, i.e. the actual travel range and changes in transit time and breakaway times.

The diagnosis runs for on/off valves in AUTO mode in the background. The function does not need to be activated. While the plant is running, breakaway time (rising/falling), transit time (rising/falling) and valve end position parameters are recorded. The first values recorded are used as a reference for further tests.

If the analysis detects an error, the positioner generates a corresponding status message.

#### 2.1.3 Valve position histogram

The valve travel histogram is a statistical analysis of the plotted valve positions. The histogram provides information about where the valve mainly spends the majority of its time during its service life and whether it shows a recent trend concerning changes in its operating range.

Data are recorded in the background regardless of the operating mode selected. A short-term histogram and a long-term histogram are plotted.

The positioner generates a status message if the analysis of the travel histogram detects a shifting working range or working range error.

#### 2.1.4 Set point deviation histogram

The set point deviation histogram contains a statistical analysis of any set point deviations recorded. This provides a summary of how often and to which level a set point deviation has occurred during the valve service life and whether it shows a recent trend concerning the set point deviation. Ideally, the set point deviation should be as small as possible.

Data are recorded in the background regardless of the operating mode selected. A short-term histogram and a long-term histogram are plotted.

The positioner generates a status message if the histogram detects a limit working range, inner leakage or connection positioner/valve error.

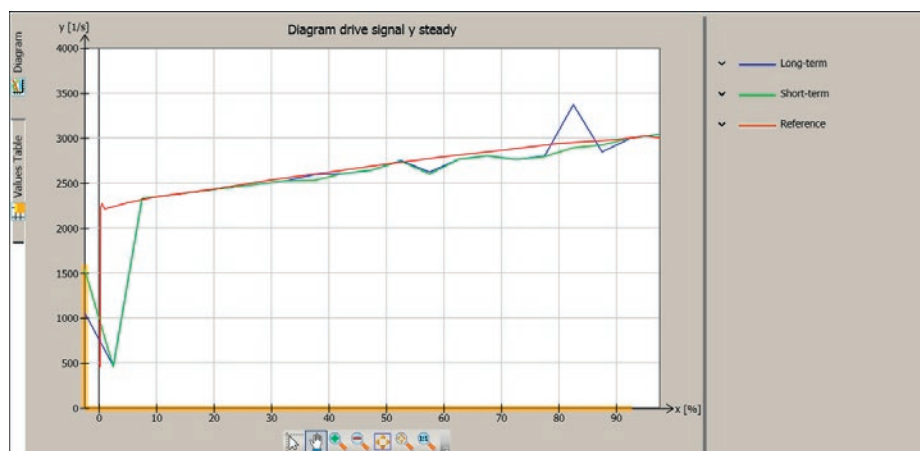


Fig. 3: Drive signal diagram steady-state

### 2.1.5 Cycle counter histogram

The cycle counter histogram provides a statistical analysis of the cycles. As a result, the cycle counter also provides information on the dynamic stress of a bellows seal and/or packing. A valve cycle span starts at the point where the valve stroke changes direction until the point where it changes direction again. The valve stroke between these two changes in direction is the cycle height.

Data are recorded in the background regardless of the operating mode selected. A short-term histogram and a long-term histogram are plotted.

If the analysis detects an error, the positioner generates a corresponding status message.

### 2.1.6 Drive signal diagram steady-state (Fig. 3)

Steady-state drive signal diagram allows changes in the supply pressure or leakage in the pneumatics to be detected. If the supply pressure is insufficient for the actuator to move through the entire bench range, this pinpoints a fault in supply pressure or leakage in the pneumatics.

Data are recorded and analyzed in the background regardless of the operating mode selected (provided a reference graph has been made). A short-term monitoring listing the measured data and a long-term monitoring in a graph are possible.

If the analysis detects an error, the positioner generates a corresponding status message.

### 2.1.7 Drive signal diagram hysteresis

The hysteresis test allows changes in friction to be analyzed. The positioner generates a status message when the results of the hysteresis test pinpoint to friction or external leakage.

If a reference graph exists, the hysteresis test can be started in both AUTO or MAN operating modes. The test can be performed once or cyclically.

A short-term monitoring listing measured data and a long-term monitoring in a graph provide an analysis of the measured data.

If the analysis detects an error, the positioner generates a corresponding status message.

### 2.1.8 Trend of travel end position

This test serves to detect wear or dirt on the valve trim and is run automatically while the process is running. The valve position is recorded when the lower end position is reached and any changes logged together with the drive signal  $y$  and a time stamp. The first measured value is used as a reference.

Shifts in the end position are registered.

## 2.2 Tests

For reasons of safety, the tests (out-of-service diagnostics) can only be started when the positioner is in the MAN operating mode. Therefore, it is important to make sure before starting a test whether the conditions (in the plant or process) allow the valve to be moved.

The tests provide a trend showing the current valve state, any possible existing malfunctions and help to pinpoint faults and to schedule predictive maintenance work.

### 2.2.1 Drive signal diagram steady-state

The drive signal diagram steady-state allows the results of the steady-state drive signal diagram in Statistical information (in-service monitoring) to be checked more closely.

After starting the test in the MAN mode, the valve moves to various fixed valve positions. The drive signal  $y$  is measured for each valve position  $x$  and compared with the reference graph. The statements on the following faults can be made:

- Supply pressure
- Pneumatic leakage or
- Actuator springs

If the analysis detects an error, the positioner generates a corresponding status message.

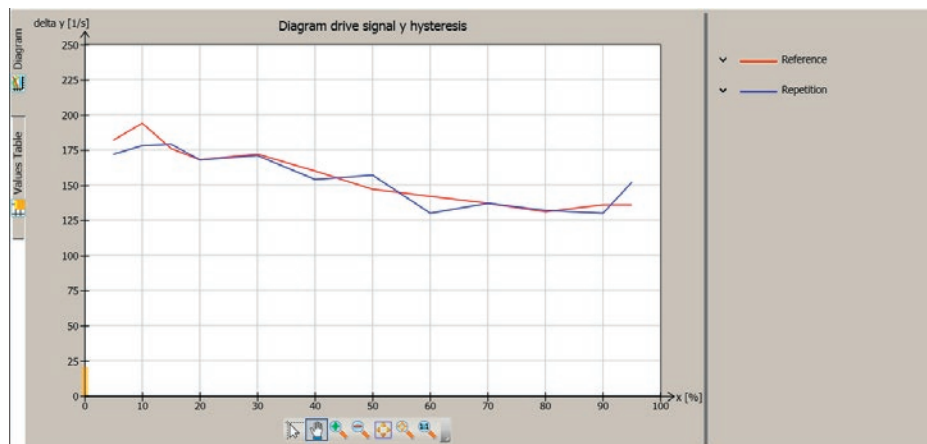


Fig. 4: Drive signal diagram hysteresis

## 2.2.2 Drive signal diagram hysteresis (Fig. 4)

The drive signal diagram hysteresis allows the results of the steady-state drive signal diagram in Statistical information (in-service monitoring) to be checked more closely. The hysteresis test allows changes in friction to be analyzed.

The test is started in the MAN mode. The valve moves to various fixed valve positions. After moving to the valve position, a ramp movement changing the valve travel is performed. The change in drive signal  $\Delta y$  is measured compared with the reference data.

The positioner generates a corresponding status message if the analysis of the drive signal pinpoints friction or external leakage.

### 2.2.3 Static characteristic

The static performance of the valve is affected by the friction hysteresis and the elastic processes in the valve stem packing.

The test is started in the MAN mode. The positioner determines the set point  $w$  in a defined test range in small steps and records the response of the valve position  $x$  after waiting a predetermined time.

An analysis of the control loop is possible from the recording and detection of min. dead band, max. dead band and average dead band.

## 2.3 Partial stroke test (PST)

Fig. 5

The partial stroke test (PST) is particularly suitable for the status-oriented detection of malfunctions in pneumatic shut-off valves. As a result, the probability of failure on demand (PFD) can be reduced and it may be possible to extend maintenance intervals. A shut-off valve normally in its end position can be prevented from seizing up or getting jammed.

The initial breakaway torque must first be overcome after the valve starts to move from its end position. The initial breakaway torque depends on the plug/seat seal, deposits on the plug, the process medium and friction at the valve trim. After the initial breakaway torque has been overcome, it can be assumed that the valve is able to close completely.

The recording of the test results additionally allows an analysis of the dynamic control response. For this purpose, the valve is moved from a defined start value, e.g. operating point, either as step response or as a ramp function to a defined point and then moved back to its original position.

As a result, the probability of failure on demand (PFD) can be reduced and it may be possible to extend maintenance intervals.

Various cancellation conditions provide additional protection against the valve slamming shut or moving past the end position:

- The maximum permissible test duration is exceeded.
- $x$  control value: The test is canceled when the value falls below the adjusted valve position.
- $\Delta y$ -monitoring: The test is canceled when the drive signal  $y$  falls below the predetermined comparison value.
- Deviation from PST tolerance band

If a partial stroke test has not been completed successfully, a status message that can be classified is generated directly reporting the failed partial stroke test at the positioner display, the engineering tool used and over the fault alarm output. This allows the summarization of safety and test functions and the addition of partial stroke testing for on/off valves in safety-instrumented systems.

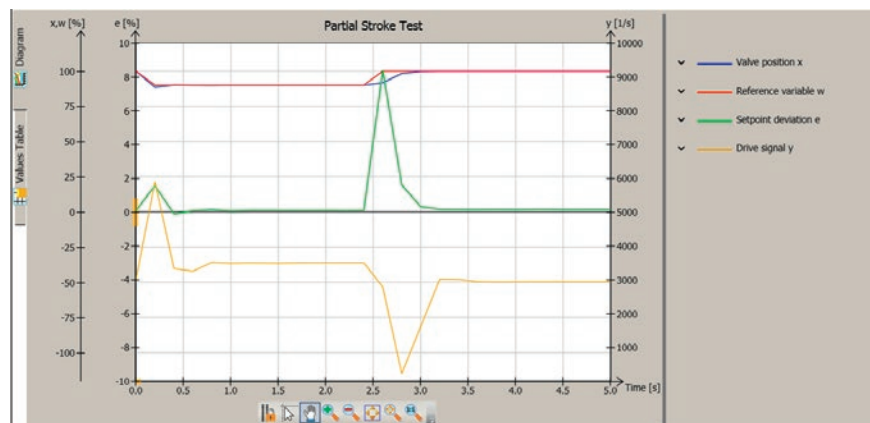


Fig. 5: Partial stroke test (PST)



## 2.4 Full stroke test (FST)

The dynamic valve performance can be evaluated by performing a full stroke test.

The valve moves through its entire working range during a full stroke test. The first step ends in the fail-safe position, while the second step starts from the fail-safe position. The change in travel can be performed either in steps or as a ramp function. For the test in a ramp function, additionally the times for the increasing and decreasing ramps need to be defined. After it is activated, the test does not start until the settling time before test start has elapsed. This ensures that the valve has reached the start position.

For reasons of safety, this test can only be started in the MAN mode.

The dynamic valve performance can be evaluated at the end of the full stroke test based on the recorded test. Full stroke tests are marked accordingly to indicate whether they have been completed successfully or not.

## 3 Visualization and parameterization of the integrated EXPERTplus diagnostics

The TROVIS-VIEW software or the DTM tool generate graphs from the data, test results and status messages collected by the diagnostic firmware in the positioner.









In addition, the diagnostic data can also be made accessible to other engineering tools using the DD (device description) or EDD (enhanced device description), which enables the data to be displayed in a graph, e.g. using Siemens PDM, AMS. How the data are displayed depends on the tool.

### 3.1 Classification and marking of status messages

Based on NAMUR recommendation NE 107, the messages (events) generated by EXPERTplus are assigned a status (classified).

The status messages can be classified as required. The classified status messages (event) are summarized in a condensed state:

#### Condensed state

Status message	TROVIS-VIEW/ DTM	Positioner
No message, OK	 green	
Function check	 orange	Text e.g. tESting, tunE, tESt
Maintenance required, maintenance demanded	 blue	
Out of specification	 yellow	 blinking
Maintenance alarm	 red	

The condensed state is indicated on the positioner display and can be read over the communication. The condensed state is also issued at the fault alarm output.

## 3.2 Graphs in TROVIS-VIEW, DTM, eDD (e.g. Siemens PDM)

The trend-viewer function in TROVIS-VIEW allows the compiled raw data and test results as well as variables (w, x, e, y) recorded in the data logger to be displayed in a graph.

The raw data and test results include:

- Current process variables
- Valve signature
- Hysteresis measurement
- Static characteristic
- Step response
- Trend of travel end position
- Partial stroke test (x, w, e, y of the current test)
- Full stroke test (x, w, e, y of the current test)

The long-term and short-term histograms described in sections 2.1.3 to 2.1.5 are displayed as bar graphs.

The long-term and short-term valve signature and histograms are available.

These graphs make any changes in positioning or control performance apparent to the user and support predictive maintenance.

## 4 Binary input

The optional binary input allows various actions to be performed which also affect the diagnostic functions. The actions are logged by the positioner.

- **Transfer switching state:** The switching state of the binary input is logged.
- **Set local operation write protection:** Settings cannot be changed at the positioner while the binary input is active.
- **Start partial stroke test (PST):** The positioner starts a single partial stroke test according to the settings.
- **Go to fail-safe reference value:** An on/off valve moves to the entered fail-safe reference value when the positioner is in automatic mode. No action is started when the positioner is in manual mode (MAN) or fail-safe position. No action is started for a control valve.
- **Switch between AUTO/MAN:** The positioner changes from AUTO mode into MAN mode and vice versa. No action is started if the positioner is in the fail-safe position.
- **Start data logger:** Activation of the binary input causes the data logger to start according to the settings.
- **Reset diagnostics:** Active functions of statistical information and tests are stopped and the diagnostic data is reset.
- **External solenoid valve connected:** The triggering of an external solenoid valve is recognized and logged.

Specifications subject to change without notice



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