Series 3730
EXPERTplus Valve Diagnostics for TROVIS SAFE 3730-6 Positioner

TROVIS SAFE

For on/off valves in safety-instrumented systems

Application

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

EXPERTplus is a diagnostic firmware integrated into the positioner which allows the predictive, status-oriented maintenance of valves with pneumatic actuators.
The diagnostic functions of EXPERTplus are completely integrated into the TROVIS SAFE 3730-6 Positioner. Diagnostic data are compiled, saved and analyzed in the positioner itself. The data are analyzed and classified status messages are generated about the condition of the valve based on the NAMUR Recommendation NE 107 on the state of the valve.

Special features

- Diagnostic firmware for on/off valves
- Start-up monitoring
- Diagnostic functions performed without any additional sensors (except for seat leakage detection using the optional leakage sensor)
- Cyclical polling of diagnosis data, multiplexer-capable
- Diagnostic data and test analysis saved in the positioner
- Logging with operating hours counter allows data and events to be sorted by time
- Automatic generation of status messages
- Status classification and condensed state based on NAMUR Recommendation NE 107
- Minimum and maximum temperature readings with details on how long the limits have been exceeded
- Classified status messages and condensed state can be read in the operator software, at the positioner display or issued at the fault alarm contact

Operator software

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.

- **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

Fig. 1: *TROVIS SAFE 3730-6 Electropneumatic Positioner with HART® communication and pressure sensors*

Fig. 2: *On/off rotary valve with TROVIS SAFE 3730-6 Electropneumatic Positioner with HART® communication and pressure sensors*

Associated Information Sheet T 6661

Data Sheet TROVIS SAFE 3730-6 Positioner T 8384-6S

Edition February 2015

Data Sheet **T 8389-1S EN**

Diagnostic functions

The diagnostic functions in EXPERTplus are divided into two categories: monitoring and dynamic tests.

- **Monitoring tests**
  Data are compiled, saved and analyzed by the positioner while the process is running without disrupting it. 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.
- **Dynamic tests**
  Similar to the monitoring tests, data are compiled, saved and analyzed by the positioner. However, in this case, the valve position is not determined by the set point, but by the active test. The dynamic 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, the dynamic tests, except for partial stroke testing, can only be performed in the MAN operating mode.

Table 1 shows the diagnostic functions with their test analyses.

Type of application (control valve or on/off valve)

Different diagnostic functions are available depending on the type of application selected in EXPERTplus. The types of application 'Control valve' and 'On/off valve' are available. Depending on the type of application selected, the positioner behaves differently in the automatic mode (AUTO):

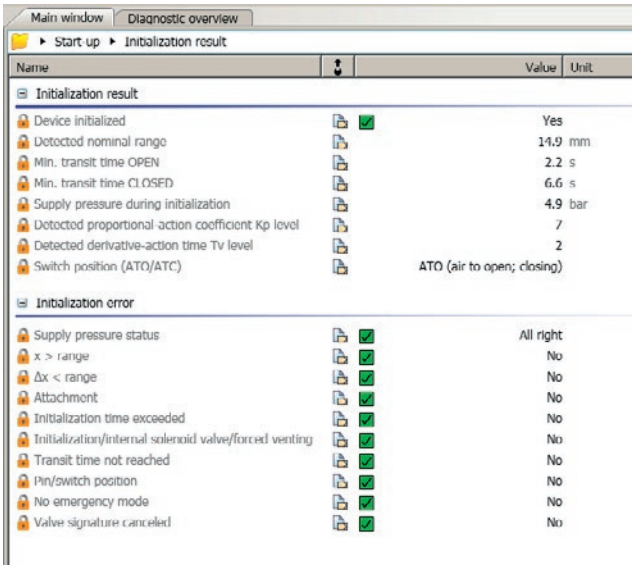
- **Control valve**
  The positioner uses the set point to position the valve. The valve position (current position) appears in % on the display.
- **On/off valve**
  Discrete analysis of the set point:
  The valve position (current position) in % and ***O/C*** (Open/Close) appear in alternating sequence on the display.
  The discrete analysis of the set point in 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 a predefined set point.

The table shows the correlation between the type of application and operating mode:

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

1 Initialization results

EXPERTplus monitors the valve during automatic initialization to ensure trouble-free start-up. For this purpose, the positioner determines the nominal range, opening and closing times of the valve as well as the control parameters, such as proportional-action coefficient (Kp level) and the derivative-action time (Tv level). Additionally, initialization errors including supply pressure status, attachment, initialization time exceeded or pin/switch position are reported.



2 Diagnostics and measured process values

EXPERTplus shows the key process variables collected by the positioner, such as set point w, valve position x, operating state, supply pressure p_s and signal pressure p_{out}. Leakage in the pneumatic system is additionally shown for control valves.

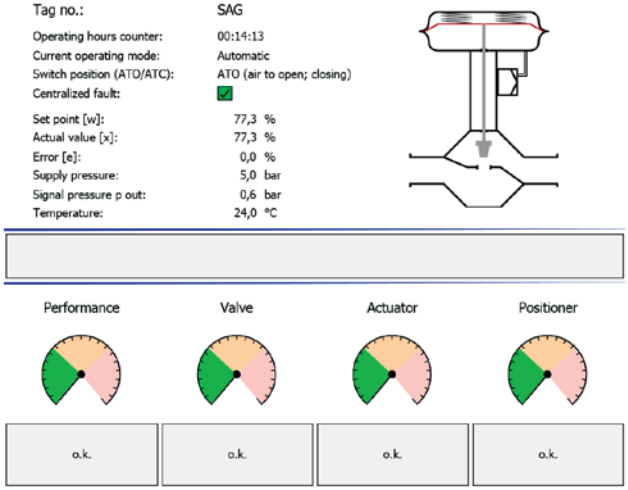


Table 1: *Overview of EXPERTplus functions*

Function	Control valve	On/off valve	Analysis	See section
Initialization result	•	•	Nominal range, min. transit times OPEN and CLOSED, supply pressure during initialization, proportional-action coefficient (Kp level), derivative-action time (Tv level), switch position ATO/ATC (closed position) **Messages:** Supply pressure status, x > range, Δx < range, attachment, initialization time exceeded, internal solenoid valve/forced venting/supply pressure, transit time reached, pin/switch position, no emergency mode, valve signature canceled	1
Measured process values	•	•	Condensed state, operating hours counter, set point w, valve position x, set point deviation e, operating status, supply pressure, signal pressure, absolute total valve travel, inside temperature, dynamic load factor, differential pressure, flow rate	2
Monitoring				
Status messages	•	•	Display and logging of classified status messages and condensed state	3.1
Condensed state	•	•		3.2
Logging	•	•		3.3
Monitoring tests				
Data logger	•	•	Depending on the trigger condition selected	4.1.1
Valve signature	•	⊗	**Messages:** Friction change, supply pressure, pneumatic leakage, actuator springs defect	4.1.2
On/off valve	–	•	Breakaway time, transit time, final travel/angle value **Message:** On/off valve status	4.1.3
Valve position histogram	•	⊗	**Messages:** Course of the manipulated variable range, manipulated variable range	4.1.4
Set point deviation histogram	•	•	Average set point deviation **Messages:** Manipulated variable range limitation, seat leakage, positioner-valve linkage	4.1.5
Cycle counter histogram	•	•	Dynamic stress factor **Message:** Packing leakage	4.1.6
Leakage sensor	•	•	**Message:** Seat leakage	4.1.7
Course of end position	•	•	Zero shift **Message:** Course of end position	4.1.8
Dynamic tests				
Valve dead band	•	•	Dead band	4.2.1
Partial stroke test (PST)	•	•	Overshooting, dead time, T86, settling time **Message:** PST/FST status	4.2.2
Full stroke test (FST)	•	•	Overshooting, dead time, T86, settling time **Message:** PST/FST status	4.2.3
Binary input	•	•	–	5

• Full scope of functions

⊗ Function is performed, but not analyzed

– Function is not performed

3 Monitoring

3.1 Status messages

The valve diagnostics integrated into the positioner generates classified status messages based on NAMUR recommendation NE 107.
Messages generated from the analysis of the diagnosis can be classified according to the possible causes.

The following classifications are possible:

- **No message**
  If an event is classified as "No message", this event does not have any affect on the condensed state.
- **Function check**
  Test or calibration procedures are performed in the positioner. The positioner is temporarily unable to perform its control task as long as the procedure is taking place.
- **Maintenance required/maintenance demanded**
  The positioner still performs its control task (with restrictions). A maintenance demand or above average wear has been determined. The wear tolerance will soon be exhausted or is reducing at a faster rate than expected. Maintenance is necessary in the medium term.
- **Out of specification**
  The positioner is running outside the specified operating conditions.
- **Failure**
  The positioner cannot perform its control task due to a functional fault in the positioner itself or in one of its peripherals or an initialization has not yet been successfully completed.

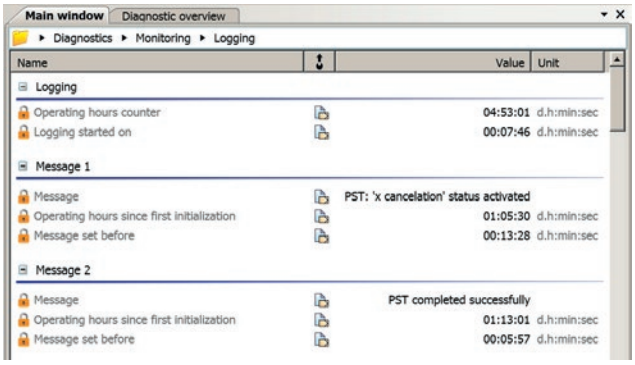
3.2 Condensed state based on NAMUR Recommendation NE 107

To provide a better overview on the condition of the valve, all status messages are summarized in a condensed state which is made up from a summary of all classified messages in the positioner. The status message with the highest priority determines which condensed state is set.
The condensed state is also issued at the fault alarm output.

Status message	TROVIS-VIEW or DTM	Positioner	Priority
Failure	red		
Function check	orange	Text e.g. ***TESTING***, ***TUNE*** or ***TEST***	
Out of specification	yellow	blinking	
Maintenance required/maintenance demanded	blue		
No message, OK	green		

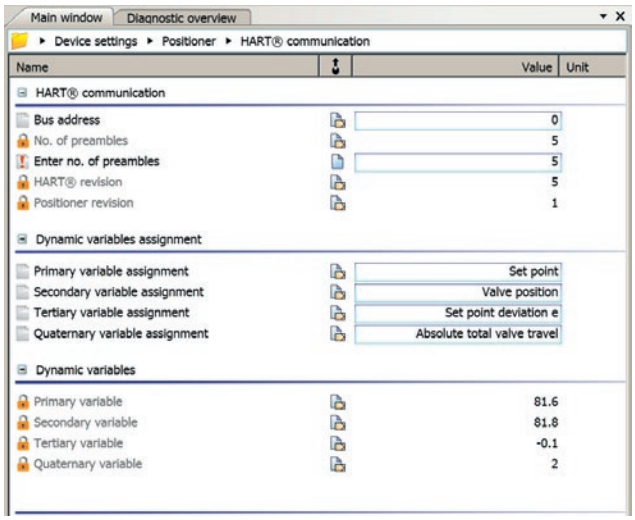
3.3 Logging

The positioner saves the last 30 plain-text messages that have been generated including time stamp and details on how long the message exists. The message logging generated by the diagnostics can be deactivated.



3.4 Dynamic HART® variables

The four dynamic HART® variables can be assigned to variables, such as set point, direction of action set point, set point after transit time specification, valve position, set point deviation, absolute total valve travel, binary input status, internal solenoid valve/forced venting status, condensed state, temperature, sound level (leakage sensor), ambient pressure, signal pressure, supply pressure, flow rate and differential pressure as well as all active errors.



4 Diagnostic functions

The analysis of diagnostic functions highlights possible valve malfunctions.

4.1 Monitoring tests

By permanently recording raw diagnostic data (w, x, p_{out} and e) in the positioner, the user can gather information about how the valve behaves under process conditions.
Signal logging enables an analysis of the current measuring scope as well as of the positioner's entire service life.

The following statements can be made, for example:
- Valve position 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.

4.1.1 Data logger

The data logger records the following variables: *valve position x, set point w, set point deviation e* and *signal pressure* p_{out}.
The recorded data are plotted against time in a graph. The last 100 data points per variable are saved in a FIFO memory in the positioner. The time between recording data points is user-definable.
In addition to permanent logging, data logging can be started automatically while the process is running, provided a defined trigger condition is met.

4.1.2 Valve signature

The valve signature plots the *signal pressure* p_{out} as a function of *valve position x*, the course of supply pressure (*supply pressure* p_s vs. the number of measurements) and friction (hysteresis vs. *valve position x*).
To perform the monitoring tests while the process is running, the reference curve (*signal pressure* p_{out} vs. *valve position x*) must be recorded first.
The valve signature allows EXPERTplus to detect the following malfunctions:
- Actuator spring compression reduced
- Zero error
- Supply pressures too high, fluctuates, too low, does not exist or the permissible limits exceeded
- Lower/higher friction change in entire range/in mid-position/near max. OPEN position/near CLOSED position

4.1.3 On/off diagnosis

The diagnostics for on/off valve provide statements on the valve end positions, transit times (increasing/decreasing) and breakaway times (increasing/decreasing).
The positioner compares the current breakaway time, transit time and valve position with the values recorded during the reference measurement while the plant is running. The first values recorded are used as a reference for further tests.
EXPERTplus generates an on/off valve message when the breakaway or transit times or the valve end position deviates from the reference value by the definable limit or the valve end position is not reached.

4.1.4 Valve position histogram

The valve travel histogram is a statistical analysis of the plotted valve positions. It provides information about where the valve mainly works during its service life and whether it shows a recent trend concerning changes in its operating range.
A short-term histogram and a long-term histogram are plotted.
EXPERTplus generates the corresponding message when the positioner mainly works near or in the CLOSED/max. OPEN position or an operating range shift is detected.

4.1.5 Set point deviation histogram

The set point deviation histogram contains a statistical analysis of any set point deviations recorded. It provides a summary of how often and to which level a set point deviation has occurred during the valve service life and whether malfunctions may arise. Ideally, the set point deviation should be as small as possible.
A short-term histogram and a long-term histogram are plotted.
EXPERTplus generates a corresponding message when the histogram pinpoints to internal valve leakage or an limitation of the upper or lower manipulated variable range.

4.1.6 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.

4.1.7 Leakage sensor

By upgrading the positioner with a leakage sensor, it is possible to detect seat leakage when the valve is in the closed position. To achieve this, the leakage sensor measures the sound pressure level (dB) while the valve is tightly shut and compares the current sound pressure level with predefined alarm limits.
To be able to use the full scope of functions, the response of the leakage sensor to standardized conditions and to the prevailing process conditions must be measured. Furthermore, the limit to activate the alarm must be entered.
The positioner generates a message if the current sound pressure level exceeds one of the limits to trigger an alarm.

Fig. 3: *Type 3241-7 Control Valve with TROVIS SAFE 3730-6 Positioner and optional leakage sensor*

4.1.8 Course of end position

The course of end position is used to detect an alternating zero point or a creeping zero point shift due to seat and plug wear or dirt between the seat and plug.
The course of the end position records the *valve position x* and the *signal pressure* p_{out} together with the time stamp by the operating hours counter when the valve moves to the lower end position. The new recorded valve position is compared to the last saved zero point.
A graph of the recorded valve positions at the lower end position is plotted over time.
EXPERTplus generates a corresponding message when the end position shifts.

4.2 Dynamic tests

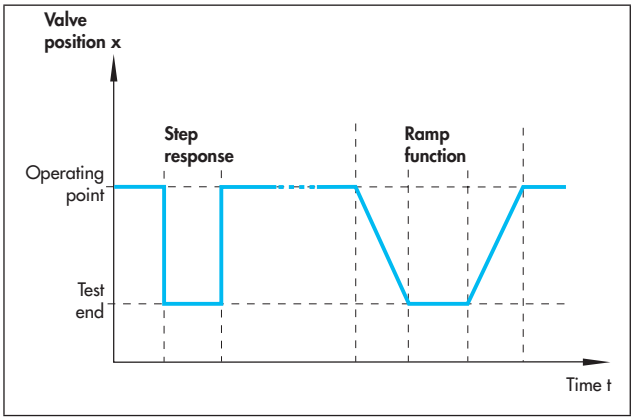
For reasons of safety, the dynamic tests can only be started when the positioner is in the MAN operating mode. Therefore, it is important to make sure before starting a test whether the conditions (in the plant or process) allow the valve to move.
The dynamic tests provide a trend showing the current valve state, any possible existing malfunctions and help to pinpoint faults and to schedule predictive maintenance work.

4.2.1 Valve dead band

The difference in *set point w* that causes a minimal change in the *valve position x* is termed 'dead band'.
The valve dead band is affected by the friction hysteresis and the elastic processes in the valve stem packing.
The positioner specifies the *set point w* in a defined test range in small steps and records the response of the *valve position x*. The ascendent and descendent are plotted within the test range. The response of the *valve position x* to the *change in set point (Δw)* is plotted in a graph.
The dead band is analyzed in the positioner when a step height is smaller than 0.2 %.

4.2.2 Partial stroke test (PST)

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.
Recording the test results additionally allows an analysis of the dynamic control response.
The partial stroke test can be performed once or, with an on/off valve in automatic mode, regularly. The partial stroke test can also be started over the binary input.
During the partial stroke test, the valve moves from its current operating point to a defined stop value and back to the initial position again. The change in travel can be performed either in steps or in a ramp function.



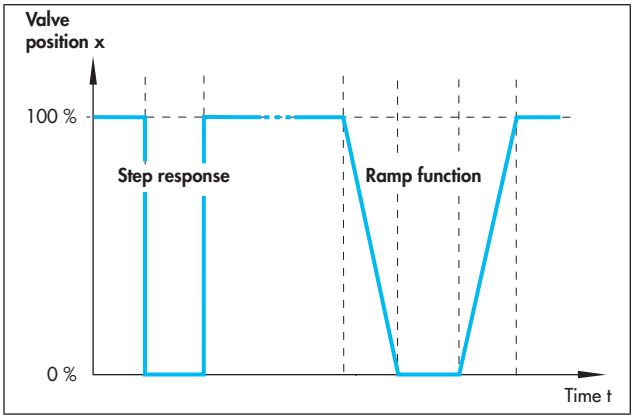
Various cancelation conditions can be activated to provide additional protection against the valve slamming shut or moving past the end position:

- The maximum permissible test duration is exceeded.
- The maximum breakaway time is exceeded.
- The permissible time until reaching the step end is exceeded.
- The valve position x falls below the adjusted value.
- Change in signal pressure undercuts or exceeds the permissible value.
- PST tolerance band is exceeded.

The analysis of the last three partial stroke tests are saved in EXPERTplus together with a time stamp. When a partial stroke test has been completed successfully, the analyzed parameters (overshooting, dead time, T86, settling time) are displayed separately for the increasing and decreasing characteristics.
EXPERTplus generates a corresponding message when the partial stroke test is not completed successfully.

4.2.3 Full stroke test (FST)

The dynamic valve performance can be evaluated by performing a full stroke test.
The valve moves through its entire manipulated variable 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.



Various cancelation conditions can be activated to provide additional protection against the valve slamming shut or moving past the end position:

– The test is canceled when the maximum permissible test duration is exceeded.
– The maximum breakaway time is exceeded.
– The permissible time until reaching the closed position is exceeded.

The analysis of the last three full stroke tests are saved in EXPERTplus together with a time stamp. When a full stroke test has been completed successfully, the analyzed parameters (overshooting, dead time, T86, settling time) are displayed separately for the increasing and decreasing characteristics.

EXPERTplus generates a corresponding message when the full stroke test is not completed successfully.

5 Binary input

The optional binary input allows various actions to be performed which also affect the diagnostic functions. If an action is started over the binary input, this action is logged.

– **Transmit switching state:** The switching state of the binary input is logged.
– **Activate local 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.
– **Move valve to safety set point:** An on/off valve moves to the entered safety set point when the positioner is in automatic mode.
– **Switch AUTO/MAN:** The positioner changes from the automatic mode to the manual mode or vice versa.
– **Start data logger:** Activation of the binary input causes the data logger to start according to the settings.
– **Reset diagnostics:** Active monitoring and dynamic tests are stopped and the diagnostic data is reset once.

Visualization and parameterization

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.

Graphs in TROVIS-VIEW 4, DTM, EDD

The Trend Viewer function in TROVIS-VIEW allows the following compiled raw data and test results as well as variables (w, x, e, p_{out}) recorded in the data logger to be displayed in a graph:

– Process variables
– Valve signature
– Course of end position
– Valve dead band
– Partial stroke test (x, w, e, p_{out} of the current test)
– Full stroke test (x, w, e, p_{out} of the current test)

The long-term and short-term monitoring tests described in sections 4.1.4 to 4.1.6 are displayed in bar graphs.
The valve signature and the histograms use long-term and short-term monitoring tests.
These graphs make any changes in positioning or control performance apparent to the user and support predictive maintenance.

Specifications subject to change without notice

SAMSON AG · MESS- UND REGELTECHNIK
Weismüllerstraße 3 · 60314 Frankfurt am Main, Germany
Phone: +49 69 4009-0 · Fax: +49 69 4009-1507
samson@samson.de · www.samson.de

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