Series 3730

EXPERTplus Valve Diagnostics for Type 3730-6 Positioner

Application
EXPERTplus evaluates the condition of the valve while the process is running (automatic mode) and provides maintenance recommendations. In addition, numerous tests are available in manual mode for pinpointing faults.

The EXPERTplus valve diagnostics can detect faults and provide predictive, status-oriented maintenance of pneumatic control valves.

The full scope of diagnostic functions is completely integrated into the Type 3730-6 Positioner. The diagnostic data are compiled, analyzed and stored in the positioner. The data are analyzed and classified status messages are generated about the condition of the valve based on the NAMUR Recommendation NE 107.

Special features
• Diagnostic firmware suitable for control and 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 diagnostic data, multiplexer-capable
• Diagnostic data and test analysis saved in the positioner
• Logging with time stamp 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 4 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 4 · Operator interface to configure and operate 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 · Control valve with Type 3730-6 Electropneumatic Positioner with HART® communication and pressure sensors

Fig. 2 · On/off rotary valve with Type 3730-6 Electropneumatic Positioner with HART® communication and pressure sensors
Diagnostic functions

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

- Monitoring (in-service)
  Data are compiled, saved and analyzed by the positioner while the process is running without disrupting the process. The positioner follows the reference variable during this time. A classified status message or error message is generated when the positioner detects an event.

- Dynamic tests (out-of-service)
  Similar to in-service monitoring, data are compiled, saved and analyzed by the positioner. However, in this case, the valve position is not determined by the reference variable, but 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, these dynamic tests, except for partial stroke testing, can only be performed in the MAN operating mode.

Table 1 shows the individual diagnostic functions with their test analyses.

Type of application

Depending on the type of application, various diagnostic functions are provided by EXPERTplus. Two types of application are available: control valve or on/off valve. The behavior in automatic mode (AUTO) differs depending on the type of application:

- Control valve
  The positioner follows continuously the reference variable. The valve position appears in % on the display.

- On/off valve
  The valve 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 (PST) can be started by entering the corresponding set point.

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

<table>
<thead>
<tr>
<th></th>
<th>Control valve</th>
<th>On/off valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTO mode</td>
<td>The positioner follows continuously the reference variable. The valve position appears in % on the display.</td>
<td>Discrete analysis of the set point. The valve position in % and O/C (Open/Close) appear in alternating sequence on the display.</td>
</tr>
<tr>
<td>MAN mode</td>
<td>The positioner follows the set point provided over local operation or acyclic communication.</td>
<td></td>
</tr>
</tbody>
</table>

### Initialization result

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 registered.

### Diagnostics overview 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>
<thead>
<tr>
<th>Test function</th>
<th>Control valve</th>
<th>On/off valve</th>
<th>Diagnosis</th>
<th>See section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initialization result</td>
<td>•</td>
<td>•</td>
<td>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) <em>Messages:</em> Supply pressure status, ( x &gt; ) range, ( x &lt; ) range, attachment, initialization time exceeded, internal solenoid valve/forced venting/supply pressure, transit time reached, pin/switch position, no emergency mode, valve signature canceled</td>
<td>1</td>
</tr>
<tr>
<td>Measured process values</td>
<td>•</td>
<td>•</td>
<td>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</td>
<td>2</td>
</tr>
<tr>
<td>Monitoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Status messages</td>
<td>•</td>
<td>•</td>
<td>Display and logging of classified status messages and the condensed state</td>
<td>3.1</td>
</tr>
<tr>
<td>Condensed state</td>
<td>•</td>
<td>•</td>
<td></td>
<td>3.2</td>
</tr>
<tr>
<td>Logging</td>
<td>•</td>
<td>•</td>
<td></td>
<td>3.3</td>
</tr>
<tr>
<td>Monitoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data logger</td>
<td>•</td>
<td>•</td>
<td>Depending on the trigger condition selected</td>
<td>4.1.1</td>
</tr>
<tr>
<td>Valve signature</td>
<td>•</td>
<td>◐</td>
<td><em>Messages:</em> Friction change, supply pressure, pneumatic leakage, actuator springs defect</td>
<td>4.1.2</td>
</tr>
<tr>
<td>On/off valve</td>
<td>–</td>
<td>•</td>
<td>Breakaway time, transit time, final travel/angle value</td>
<td>4.1.3</td>
</tr>
<tr>
<td>Valve position histogram</td>
<td>•</td>
<td>◐</td>
<td><em>Messages:</em> Course of the manipulated variable range, manipulated variable range</td>
<td>4.1.4</td>
</tr>
<tr>
<td>Set point deviation histogram</td>
<td>•</td>
<td>•</td>
<td>Mean set point deviation</td>
<td>4.1.5</td>
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<tr>
<td>Cycle counter histogram</td>
<td>•</td>
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<td>Dynamic load factor</td>
<td>4.1.6</td>
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<tr>
<td>Leakage sensor</td>
<td>•</td>
<td>•</td>
<td><em>Message:</em> Seat leakage</td>
<td>4.1.7</td>
</tr>
<tr>
<td>Course of end position</td>
<td>•</td>
<td>•</td>
<td>Zero point shift</td>
<td>4.1.8</td>
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<tr>
<td>Dynamic tests</td>
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<tr>
<td>Valve dead band</td>
<td>•</td>
<td>•</td>
<td>Dead band</td>
<td>4.2.1</td>
</tr>
<tr>
<td>Partial stroke test (PST)</td>
<td>•</td>
<td>•</td>
<td>Overshooting, dead time, T86, settling time</td>
<td>4.2.2</td>
</tr>
<tr>
<td>Full stroke test (FST)</td>
<td>•</td>
<td>•</td>
<td>Overshooting, dead time, T86, settling time</td>
<td>4.2.2</td>
</tr>
<tr>
<td>Flow rate calculation</td>
<td>•</td>
<td>•</td>
<td>Flow rate</td>
<td>5</td>
</tr>
<tr>
<td>Binary input</td>
<td>•</td>
<td>–</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

- Full scope of functions
- ◐ Function is performed, but not assessed
- – Function is not performed
3. Monitoring

3.1 Status messages
The positioner contains integrated diagnostics to generate status messages classified based on NAMUR recommendation NE 107.

Messages generated by the diagnostics can be classified. 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 of the positioner.

- **Function check**
  Test or calibration procedures are performed in the positioner. The positioner is temporarily unable to follow 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 operated outside specified operating conditions.

- **Failure**
  The positioner cannot perform its control task due to a malfunction in the positioner itself or in one of its peripherals or an initialization has not yet been successfully completed.

3.2 Condensed state according to NAMUR Recommendation NE 107
To provide a better overview about the condition of the valve, all status messages are summarized in a condensed state which is made up from a summary of all classified positioner messages. The status message with highest priority determines the condensed state.

The condensed state is also issued at the fault alarm output.

<table>
<thead>
<tr>
<th>Status message</th>
<th>TROVIS-VIEW 4 or DTM</th>
<th>Positioner</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function check</td>
<td>orange</td>
<td>Text, e.g. TESTING, TUNE or TEST</td>
<td></td>
</tr>
<tr>
<td>Failure</td>
<td>red</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out of specification</td>
<td>yellow</td>
<td></td>
<td>blinking</td>
</tr>
<tr>
<td>Maintenance required/demanded</td>
<td>blue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No message, OK</td>
<td>green</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 \( (w, x, p_{out}, \text{and } e) \) in the positioner, the user can gather information about how the valve behaves under process conditions.

Signal logging enables an analysis of the selected section of time as well as throughout the positioner’s service life.

The following statements can be made, for example:

- Valve position range OK
- Valve mainly operates in one of the end position
- Dynamic load 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 \( p_{out} \).

These data are plotted over 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 \( (\text{supply pressure } p_s \text{ versus the number of measurements}) \) and friction (hysteresis versus Valve position \( x \)).

To perform the monitoring while the process is running, the reference curve \( (\text{signal pressure } p_{out} \text{ versus Valve position } x) \) must first be plotted.

The valve signature allows EXPERTplus to detect the following malfunctions:

- Actuator spring compression reduced
- Zero point 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 Diagnostics for on/off valve

The diagnostics for on/off valve provides statements on the valve end positions, transit times (increasing/decreasing) and breakaway times (increasing/decreasing).

While the plant is running, the positioner compares the momentary transit times and breakaway times as well as the momentary travel with the values determined during the reference measurement. The first recorded data are used as the reference measurement 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 position 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.

A short-term histogram and a long-term histogram are generated.

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 deviations in the set point (errors). This 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 generated.

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 cycle span or cycle height. As a result, the cycle counter also provides information on the dynamic load 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.

EXPERTplus generates a message if the current sound pressure level exceeds one of the alarm limits.

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Type 3241-7 Control Valve with Type 3730-6 Positioner and optional leakage sensor
4.1.8 Course of end position
The course of end position is used to detect a fluctuating zero point or a creeping zero point shift due to seat and plug wear or dirt between the seat and plug.
The course of end position records the Valve position \(x\) and the Signal pressure \(p_{out}\) with a 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 zero point. If it differs from the last value by a defined limit, the data of the new zero point are saved.
A graph of the recorded end positions is plotted.
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. The valve moves through its operating range after a test starts. 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 control valve state, any possible existing malfunctions and help to pinpoint faults and to schedule predictive maintenance work.

4.2.1 Valve 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 \(w\) 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 pneumatic shut-off valve malfunctions. As a result, the probability of failure on demand (PFD) can be reduced and it may be possible to extend maintenance intervals.
In this way, a valve normally in its end position can be prevented from seizing up or getting jammed. The dynamic valve performance can also be assessed by performing a partial stroke test.
The partial stroke test can be performed once or according to a schedule for an on/off valve in automatic mode. Additionally, the partial stroke test can be started over the binary input.
During the partial stroke test, the valve moves from the momentary operating value to a defined end 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 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 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, the assessed parameters (overshooting, dead time, T86, settling time) are shown separately for the increasing and decreasing characteristic. 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 assessed 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 provide additional protection against the valve slamming shut or moving past the end position. The test is canceled when:
- The maximum 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, the assessed parameters (overshooting, dead time, T86, settling time) are shown separately for the increasing and decreasing characteristic. EXPERTplus generates a corresponding message when the full stroke test is not completed successfully.
5. Calculated flow rate

Due to the differential pressure measurement $\Delta p_{\text{out}}$, EXPERTplus is able to calculate the flow rate in a SAMSON Type 3241 or Type 3251 Valve, provided all the parameters regarding the medium and the process have been defined in the positioner.

6. 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.

- **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 safety set point:** An on/off valve moves to the entered safety set point when the positioner is in automatic mode.
- **Switch between AUTO/MAN:** The positioner changes from AUTO mode into MAN mode and vice versa.
- **Start data logger:** The data logger is started according to the settings when the binary input is active.
- **Reset diagnosis:** Active diagnostic functions are canceled and a single reset of the diagnosis data performed.

**Visualization and parameterization**

The TROVIS-VIEW 4 software or the DTM tool generates graphs from the data, test results and status alarms 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 data to be displayed in a graph:

- Compiled raw data
- Test results including:
  - Process variables
  - Valve signature
  - Course of end position
  - Valve dead band
  - Partial stroke test ($x, w, e, \Delta p_{\text{out}}$ of the current test)
  - Full stroke test ($x, w, e, \Delta p_{\text{out}}$ of the current test)
- Variables ($w, x, e, \Delta p_{\text{out}}$) recorded in the data logger.

The long-term and short-term monitoring 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. These graphs make any changes in positioning or control performance apparent to the user and support predictive maintenance.