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РЕШЕНИЯ ДЛЯ ПРОВЕДЕНИЯ ИЗМЕРЕНИЙ

PipePatrol

1.1 Intended use

PipePatrol is a leak detection and localisation system for liquid and gas pipelines which operates in the stand-alone mode without any human interaction. It can be used during pumping, ramp-up, ramp-down, shut in and standstill conditions and allows continuous montitoring during all operating conditions. Additionally functionalities are the batch tracking and the instrument error analysis.

1.2 Safety instructions from the manufacturer

1.2.1 Copyright and data protection

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We hereby expressly prohibit the use of the contact data published as part of our duty to publish an imprint for the purpose of sending us any advertising or informational materials that we have not expressly requested.

1.2.2 Disclaimer

The manufacturer will not be liable for any damage of any kind by using its product, including, but not limited to direct, indirect or incidental and consequential damages.

This disclaimer does not apply in case the manufacturer has acted on purpose or with gross negligence. In the event any applicable law does not allow such limitations on implied warranties or the exclusion of limitation of certain damages, you may, if such law applies to you, not be subject to some or all of the above disclaimer, exclusions or limitations.

Any product purchased from the manufacturer is warranted in accordance with the relevant product documentation and our Terms and Conditions of Sale.

The manufacturer reserves the right to alter the content of its documents, including this disclaimer in any way, at any time, for any reason, without prior notification, and will not be liable in any way for possible consequences of such changes.

1.2.3 Product liability and warranty

The operator shall bear responsibility for the suitability of the device for the specific purpose. The manufacturer accepts no liability for the consequences of misuse by the operator. Improper installation and operation of the devices (systems) will cause the warranty to be void. The respective "Standard Terms and Conditions" which form the basis for the sales contract shall also apply.

1.2.4 Information concerning the documentation

To prevent any injury to the user or damage to the device it is essential that you read the information in this document and observe applicable national standards, safety requirements and accident prevention regulations.

If this document is not in your native language and if you have any problems understanding the text, we advise you to contact your local office for assistance. The manufacturer can not accept responsibility for any damage or injury caused by misunderstanding of the information in this document.

This document is provided to help you establish operating conditions, which will permit safe and efficient use of this device. Special considerations and precautions are also described in the document, which appear in the form of underneath icons.

2 DEVICE DESCRIPTION

2.1 Functionality

INFORMATION!
For detailed overview about the system architecture please refer to the "Functional Design Specification (FDS)" of the project.

The PipePatrol leak detection system (LDS) station will be configured to provide the following main features:

Monitoring Station (LDS server)

- Leak detection and localisation in pumping and standstill conditions
- Calculation of the leak rate
- Calculation of the leak location
- Remote maintenance via a remote access gateway (if connection is available)
- Alarming
- Data logging and event reporting
- Storing of reports and other data

Operator Station (LDS client)

- Visualisation of the running leak detection system
- Alarming (visual and acoustic)
- Trending
- Event logging
- Controlling & operating functions

2.2 Hardware installation

The Monitoring Station (MS) is completely installed before the start-up. No further installation is required.

2.3 Principle of Extended Real Time Transient Model (E-RTTM)

According to API 1130, leak detection systems can be categorised into external and internal systems. External systems include acoustic sensors and sensing cables that are placed alongside the pipeline. Due to the extremely high installation costs the use of external systems is usually restricted to high risk areas such as nature protection areas and near rivers. Internal systems are systems that perform leak detection based on measured parameters such as flow, pressure and temperature.

PipePatrol is an internal system based on E-RTTM (Extended Real Time Transient Model) and SMB (Statistical Mass Balance).

E-RTTM

E-RTTM is a combination of RTTM and leak pattern recognition by means of statistical analysis.

The fundamental principle is that RTTM is a series of algorithms that allow calculation of the flow, based solely on pressure and temperature readings at the inlet and outlet of the pipeline. To do this RTTM uses the conservation laws for mass, momentum and energy and the thermodynamic state equations for pressure and enthalpy.

When applying RTTM algorithms, the flow is not only measured by flowmeters but also calculated from pressure and temperature readings at the inlet and outlet. Subtracting the calculated flow from the measured flow gives the flow residual. Combining the two flow residuals gives the true flow residual (inlet minus outlet). The RTTM algorithms compensate for medium compressibility and line expansion.

leak pattern recognition

Basically the leak pattern recognition algorithm constantly monitors whether the residual (difference between inlet and outlet flow after the transient effects have been compensated for by RTTM) exceed a predefined threshold. If this threshold is exceeded statistical analysis will be used to determine whether this is caused by a true leak or by a sensor drift.

SMB

SMB is a combination of compensated mass balance and leak pattern recognition by means of statistical analysis.

Compensated mass balance method is based on the equation of conservation of mass. The result of this equation is permanently passed to the leak pattern recognition, which analyses it statistical to avoid false alarms.

2.4 Leak localisation method

To idendify the source of the leak accuratley the following 3 localisation methods are combined in PipePatrol.

Gradient Intersection Method

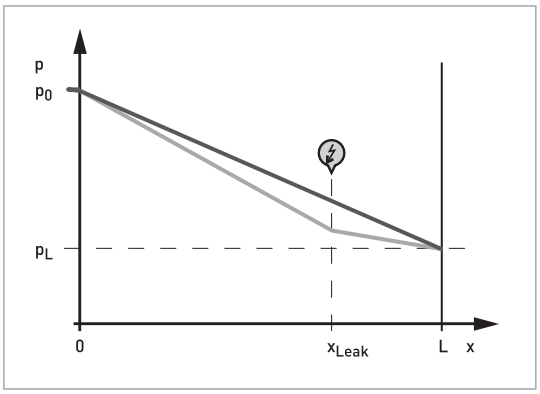


Figure 2-1: Gradient Intersection Method

Under zero leak conditions, pressure drops uniformly along the pipeline. When a leak occurs, more liquid or gas flows through the pipeline before the leak than after it.

The pressure gradient along the pipeline therefore changes at the leak. The leak localisation can thus be identified at the point where the gradient changes.

Wave Propagation Method

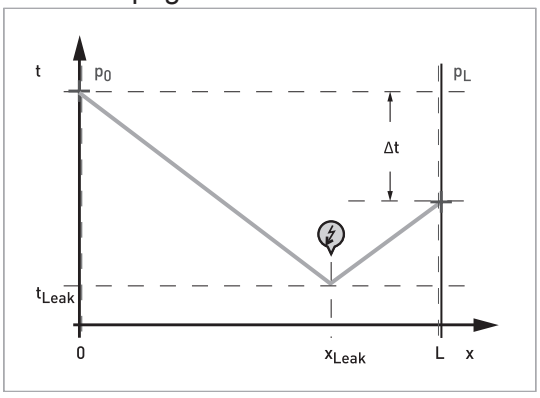


Figure 2-2: Wave Propagation Method

A sudden leak will cause a negative pressure wave in the pipeline, simply because gas or liquid is leaking out. This pressure wave will travel through the pipeline at the sound velocity of gas or liquid.

Depending on the localisation of the leak, the pressure wave will arrive at one end of the pipeline before it arrives at the other. The leak position can be calculated from the difference in the arrival times at the inlet and outlet.

Extended Wave Propagation Method

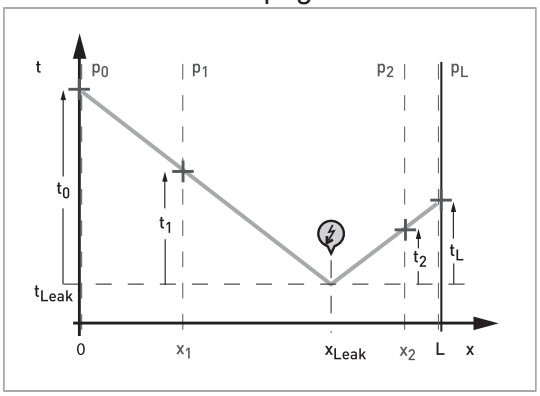


Figure 2-3: Extended Wave Propagation Method

Using the same physical principle as the wave propagation method, the extended method takes into account intermediate station measurements. Using the information from intermediate stations and E-RTTM's knowledge about the velocity of sound profile in the pipeline, jitter error introduced by slow sensor scan rates can be eliminated.

3.2 Start-up

The LDS software is automatically loaded after the monitoring station has been switched on. The software automatically starts to record measurement data and reaches its operational state shortly after start-up.

For the correct operation of the system, the following items should be considered:

- An uninterrupted power supply is required. Power supply variations can lead to re-starting of the computer and in the worst case cause the PC to crash.
- The data communication between monitoring station and the metering system must be running in order for the system to receive measurement data.

3.3 Layout of user interface

The main screen is the interface between the user and the leak detection system. The menu layout and the different windows are shown in the following drawing.

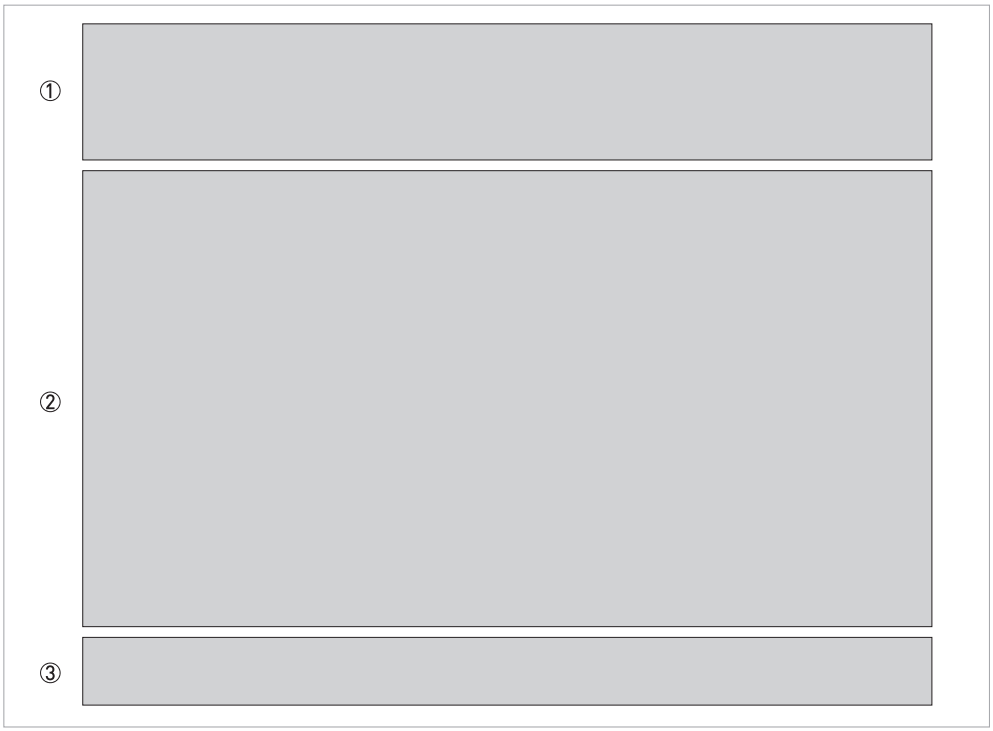


Figure 3-1: Layout of user interface

1 Status window
2 Operator window
3 Controls

3.3.1 Status window

The status window shows main information of each applicable system, which is available on each screen of the PipePatrol HMI. The functionality of each information is explained in the following part.

1 **General information from the operator station**

The operator station is the PC where the actual HMI is running.

The following information can be shown:

- Name of the user who is logged in
- Date and time of the operator station machine
- Error OPC Connection (red/flashing)
  The connection to the OPC server of the leak detection software is lost.

2 **Name of the leak detection system**

The operator station HMI is designed to be able to monitor several running leak detection systems which are designated by a unique system name. A click on one of the systems, switches the operator screen to the leak information of the selected leak detection system.

3 **Alarm information of the running leak detection**

The system performs leak detection by using different modules. Each module provides alarm information by Signature-Test and Differential-Test. The usage of these modules depends on the actual running conditions of the pipeline.

- **Shut-in:** This module is performing an analysis of the pressure reading inside the closed pipe section. As long one of the reading is available it will perform leak detection for standstill conditions.
- **ERTTM:** This module indicates the model based leak detection. It will be activated as long flow, pressure and temperature readings are available.
- **Mass Balance:** This module offers a statistical analysis of the inlet and outlet flow. As long both readings are available it will provide leak detection in pumping conditions.
- Following additional modules, following the same operating philosophy, may be available:
  - Virtual Flow
  - Su station Monitoring

The following information can be shown:

- **Undefined (blue):** LDS is not running; no leak information is available.
- **Unknown (blue):** LDS is starting-up; leak information will be available soon.
- **No Leak (grey):** The system is running; no leak is detected.
- **Leak Alarm (flashing):** The system is up and running and a leak has been detected.
- **Acknowledged alarm (blue):** An alarm has been detected and confirmed by a logged operator.

4 **State information of the running detection**

The following state information are available:

- **Main State:** Indication of the main systems states.
- **Pipeline State:** Indication of the actual pipeline conditions.
- **Watchdog:** Indication of the actual status of the watchdog monitoring.
- **Data State:** Indication of the actual status of data gathering.
- Indication of the status of vapour monitoring along the line.

For detailed information refer to the following details.

Main State

A click on the "Main State" box of a system enables the change of the actual state.

The following information can be shown:

- **Undefined (blue):** The system is not running; no system information is available.
- **Stopped (red):** The system is stopped. The recording of data is still running.
- **Online-Mode (green):** The system is running by using the current measured pipeline data.
- **Self Test-Mode (yellow):** The system is running by using the recorded pipeline data.
- **Tuning-Mode (blue):** Maintenance activities are carried out on the monitoring station. Therefore the leak detection is stopped at the moment.
- **Application alarm (red):** An internal error of the leak detection software has been detected. System stopped working. A logged operator has to reset the alarm and to restart the system. If the failure occurs several times please contact our support.
- **Error (red):** The application is not running correctly.

Pipeline State

The following information can be shown:

- **Undefined (blue):** The system is not running; no information is available.
- **Unknown (blue):** The system is filling up the internal FIFOs. There is not enough information available to estimate the pipeline conditions (possible after a restart of the system). The information will be available soon.
- **Shut-In (blue):** The pipeline is running in shut-in conditions. Valves at the inlet and at the outlet are closed.
- **Multi Shut-In (blue):** All valves are closed.
- **Partial Shut-In (blue):** At least one section is closed.
- **Blocked Line (blue):** Minimum one valve is closed, either at the inlet or at the outlet.
- **Standstill (blue):** No flow conditions along the line. The flow readings are below a predefined value. Valves at the inlet and at the outlet are opened.
- **Start-Up (blue):** The pipeline start-up with pumping operations. The flow readings are above a predefined value.
- **Shutdown (blue):** The pumping operations stopped.
- **Nominal unknown (blue):** The pipeline is running in pumping conditions at nominal flow level. The system is filling the internal FIFOs. There is not enough information available to estimate further exact pipeline conditions (possible after a restart of the system). Further pipeline information about pipeline conditions will be available soon.
- **Nominal high transient (blue):** The pipeline is running in pumping conditions at nominal flow level. High transient conditions detected by high variation of flow readings.

Watchdog

A click on the "Watchdog" box of one of the systems opens a dialogue windows which is showing all available counters, monitored by the HMI.

The following information can be shown:

- **OK:** The watchdog counter of the system is updated within the timeout range.
- **Alarm (red flashing):** The watchdog counter of the system is not updated and exceeds the timeout range. The system might be not working correctly.

Data State

The following information can be shown:

- **Undefined:** The system is not running; no information is available.
- **Unknown:** The system is filling the internal FIFOs. There is not enough information available to estimate the pipeline conditions (possible after a restart of the system). The information will be available soon.
- **OK (green):** All measured data is available.
- **Warning (yellow):** Minimum one measured data is not available. This measurement is not essential for the functionality of the LDS. The system is working by using fall back values.
- **Error (red):** Minimum one measured data is not available. This measurement is essential for the functionality of the LDS. The system holds functionality until the necessary measurements are back online.

Vapour State

The following information can be shown:

- **Undefined:** The system is not running; no information is available.
- **No (green):** The pressure along the line is above the predefined vapour pressure (product property).
- **Warning (yellow):** The pressure along the line is reaching the area of predefined vapour pressure (product property).
- **Small (red):** The pressure along the line is slightly below the predefined vapour pressure (product property). Small cavitation can be expected.
- **Large (red):** The pressure along the line is below the predefined vapour pressure (product property). Large cavitation can be expected.
- **Error (red):** There is not enough information available to estimate the vapour conditions (possible reason is no pressure readings are available).

3.3.2 Controls

The control buttons, at the bottom of the screen, enable to switch between different screens. The offered buttons and their functionality depend on the actual showed screen. The meaning of them will be explained in detail in the next chapters. The following buttons are available on each screen:

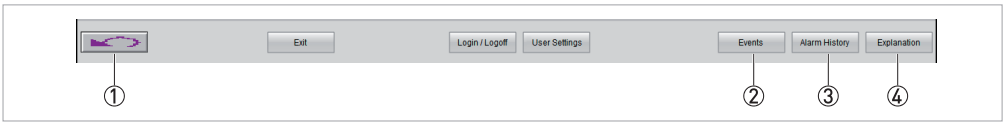


Figure 3-2: Control buttons

1 Button to switch to last showed screen 2
Events
3 Alarm History
4 Explanation

1 Last showed screen:
Switch back to the last showed screen.
(After a start-up of the HMI this button has no functionality)

2 Shows the event list (for details refer to *Events* on page 26).

3 Shows the alarm history (for details refer to *Alarm history* on page 29).

4 Shows the legend screen (for details refer to *Explanation (Legend)* on page 30).

3.3.3 Operator windows

The operator window is the essential part of the PipePatrol HMI. With this screen the operator can look on the details of each running leak detection system, monitor the behaviour and control the system. The actual showed information depends on the selected screen.

Description of the offered screen architecture of the HMI

Main Overview
- Leak Information
  - Trends
- Pipeline Overview
  - Trends
- Login/Logoff User
- Settings Exit
- Events
- Alarm History
- Explanation

3.3.4 Main Overview

An overview of the most important data for all pipelines is given in the "Main Overview". This screen is also the start-up screen after a reboot of the station computer.

For each pipeline that is included in the leak detection system, the following information can be seen:

- Actual volume/mass flow at inlet and outlet
- Actual temperature and pressure at inlet and outlet
- Description of the product at inlet and outlet (multi-product applications only)
- Graphical tracking of batches in the pipeline (for fluids applications only)

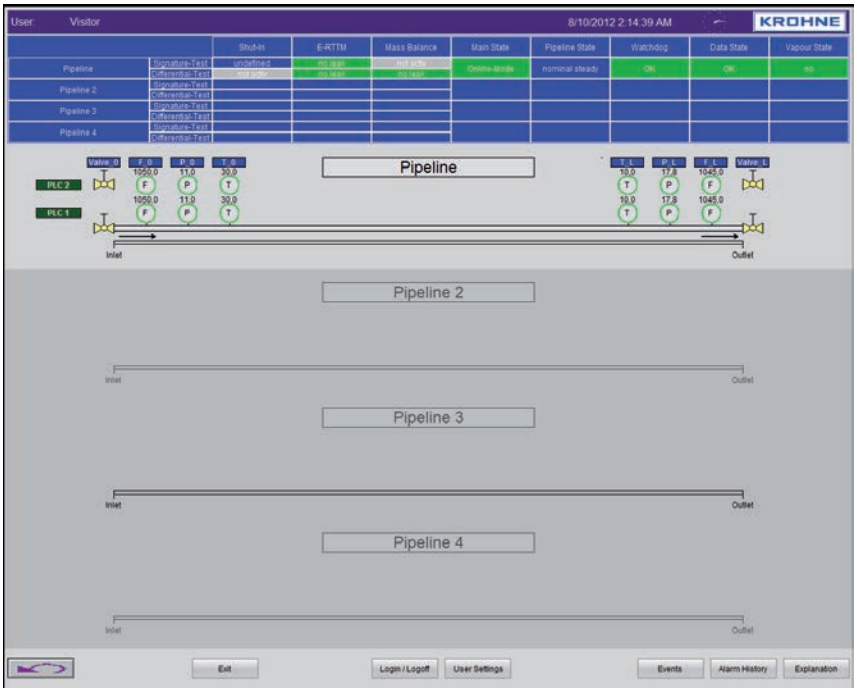
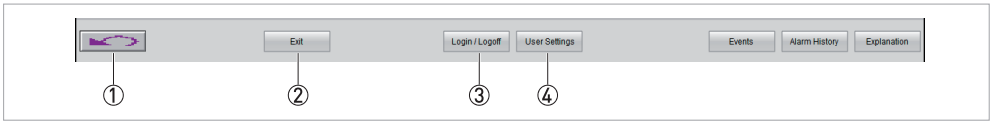


Figure 3-3: Main Overview screen

INFORMATION!
With a click on one of the available pipelines, the HMI will switch to the particular "Pipeline Overview" screen (details on page 20).

The following controls, at the bottom of the screen, are available on this screen:



1 **Last showed screen**
Switch back to the last showed screen.
(After a start-up of the HMI this button has no functionality)

2 **Exit/Shutdown the Operator Station**
Menu to stop the HMI and get back to Windows or to shut down the machine.

3 **Login/Logoff**
At start-up, the system logs in automatically the visitor account. This account only allows to view the process data. To get unrestricted access the user has to log in as a specific user. To do this, click on the "Login/Logoff" button. This button is only available from the "Main Overview" screen.
If the operator is already logged in, the first click logs the account off. A second click on the button opens a dialogue box with request of login data. With "OK" the system proves the input and grants access.
The system is delivered with a list of predefined users. That allows the operator crew to log into the system immediately.

Note: If the current operator doesn't take any actions for more than 3 minutes, his account will be automatically locked.

4 **User Settings**
Menu for administration of the HMI user accounts. The details are part of the functional design specifications (FDS).

3.3.5 Pipeline Overview

By selecting one of the pipelines showed on the "Main Overview", a detailed overview of this particular pipeline will be displayed. In this paragraph the pipeline details for pipeline 1 are described, details are however exactly similar for all pipelines.

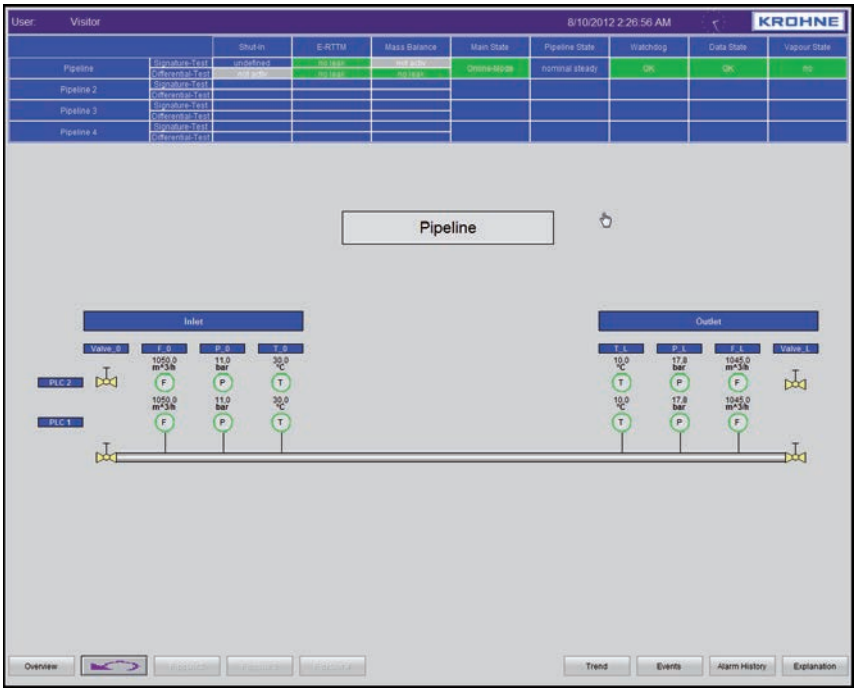


Figure 3-4: Example of pipeline details

The following data is shown:

- Actual volume/mass flow at inlet and outlet
- Actual pressure at inlet and outlet
- Actual product temperature at inlet and outlet
- Actual ground temperature at inlet and outlet (optional)
- Actual density at inlet and outlet (optional)
- Actual standardised flow at inlet and outlet (optional)
- Velocity of sound at inlet and outlet (optional)
- Actual measurement data of additional sensors (e.g. intermediate stations, optional)
- Actual state of measurement
  - (grey): unknown
  - (green): OK
  - (red): faulty
- Valves position at inlet and outlet (optional)
  - (grey): unknown
  - (black): closed
  - (yellow): open
  - (yellow/grey): moving
  - (red): faulty

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