Evolution of diagnostics

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Endress+Hauser
diagnostics in automotive industry

Service technician

- As detailed as possible
- Includes suggestions for possible remedies

Driver

- All information for safe driving
- Only essential information, summary messages
- As early as possible
diagnostics in process industry

Reliability Manager

- All information for safe operation
- Only essential information, summary messages
- As early as possible

Maintenance technician
- As detailed as possible
- Includes suggestions for possible remedies

Process operator
Purpose of diagnostics

• Analyze status information (i.e. from field devices)
• With the objective of detecting causes for potential malfunction.

Diagnostics form the basis to remove malfunctions

Value of diagnostics:
• Minimizes ad-hoc maintenance
• Enables proactive maintenance
• Minimizes unwanted plant shutdowns
• Enables event triggered inspections
• Forms the basis for Plant Asset Management
• Reduces costs
Evolution of the process signal

Conventional (4-20 mA)

- Analog
- Digital (hybrid)
- Digital (hybrid) + Status code
- Main process value + Status code
- 2nd Cyclic value + Status code
- 3rd Cyclic value + Status code
- 4th Cyclic value + Status code
- ...th Cyclic value + Status code
Diagnostics

• Acyclic access to diagnostics
• Commands for transmitting diagnostics data
  • **Command 0** (Read Unique Identifier): *Universal Command*, supported by every HART device.
    • Response Code (2nd Byte): Field Device Malfunction + More Status available
  • **Command 48** (Read Additional Transmitter Status): *Common Practice Command*, containing the device status
    • Additional generic device status information
  • **Command 231**: *Manufacturer Specific Command* (Endress+Hauser) for transmission of diagnostics data
    • Transmission of failure number and NE107- Category (MFCS)
Diagnostics

- Continuous transmission of device status (Status)
- Event-triggered transmission of device status (Diagnostics)
- Slot index for transmitting diagnostics data
Diagnostics

- Continuous transmission of device status (Status)
  - Automatically and used for control (Status Propagation)
- Event-triggered transmission of device status (Diagnostics)
- Device diagnostic can be reflected in different parts of a FOUNDATION Fieldbus device
  - Device specific diagnostic parameter
    e.g. Transducer Block parameter
  - Transducer Error
  - Block error
  - Alarms
Status propagation

Transducer Block

Transmission to AI
PV = 110
GoodNC Non-Specific

Analogue Input Block

High High Limit = 120
High Limit = 105
Low Limit = 5
Low Low Limit = 0

Transmission to Bus / Linked Block
PV = 110
GoodNC Non-Specific High limited
Status propagation

Transducer Block

Transmission to AI
PV = 50
Bad Non-Specific

Analogue Input Block

High High Limit = 120
High Limit = 105
Low Limit = 5
Low Low Limit = 0

Transmission to Bus / Linked Block
PV = 50
Bad Non-Specific Not Limited
## Block error

<table>
<thead>
<tr>
<th>Block Error Bit</th>
<th>Resource Block</th>
<th>Transducer Block Input</th>
<th>Transducer Block Output</th>
<th>Transducer Block Display</th>
<th>Function Block Input</th>
<th>Function Block Control</th>
<th>Function Block Output</th>
<th>Function Block Calc</th>
<th>Function Block Flex</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 = Other (LSB) *</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = Block Configuration Error</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>2 = Link Configuration Error</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 = Simulate Active**</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 = Local Override</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>5 = Device Fault State Set</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 = Device Needs Maintenance Soon</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 = Sensor Failure detected by this block/process variable has a status of BAD, Sensor Failure</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 = Output Failure detected by this block/backcalculation input has a status of BAD, Device Failure</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 = Memory Failure</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 = Lost Static Data</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 = Lost NV Data</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 = Readback Check Failed</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 = Device Needs Maintenance Now</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 = Power-up</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 = Out-of-Service (MSB) *</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
Important development milestones

1986 - Developed By Rosemount
1989 - Open Standard
1993 - HCF
2003 - PROFIBUS PA
2005 - Standard Device Profile 3.0
2005 - PROFIsafe Cond. Status Profile 3.01
2005 - Device Integration Profile 3.02
1989 - PNO
1995 - Founding of PI
1999 - Fieldbus Foundation
1999 - High Speed Ethernet
1999 - Safety Instrumented Functions (SIF)
2000 - FOUNDATION Fieldbus H1
2008 - Diagnostic Profiles Specification
2011 - Registered Host Profile '61b'
2007 - 2008 - HART 7 specification
2008 - HART added to IEC-61158

△ = 7 year

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AUSTIN, Texas, April 20, 2011 — The Fieldbus Foundation today announced it has registered the first two FOUNDATION fieldbus hosts incorporating new, mandatory host profile “61b “…
…verifying their support for NAMUR NE107 field diagnostics, which is now required as part of the second phase of host testing and registration.
NAMUR Recommendations

**NE 43 (1988):** Standardization of the Signal Level for Failure Information
- Discrimination between process and failure information
- μP based devices

![Current ranges for signal levels of digital transmitters](image)

**NE 107 (2005):** Self-Monitoring and diagnostics of Field Devices Diagnostics
- Analyze status information (i.e. from field devices)
- With the objective of detecting causes for potential malfunction. Diagnostics form the basis to remove malfunctions.
NE107 Self-Monitoring and diagnostics of Field Devices:

- diagnostics results must be **reliable**, bad diagnostic is worse than none at all.
- The diagnostics results must always be viewed in the context of the application.
- Each diagnostic information must be mapped to one of the four categories (FMCS)
- The **configuration** of the mapping between the diagnostic and the category should be free but predefined.
- The plant operator to see only the **status signals**.
- **Detailed information** can be read out by the device specialist.
NAMUR Categories (FMCS)

Failure – F
• The device provides a non-valid output signal due to some malfunction at the device level.

Maintenance required – M
• Although the device is still able to provide a valid output signal, the device is about to lose some of its functionality or capability due to some external operation conditions. The maintenance can be needed short-term or mid-term.

Check function – C
• The device is temporary non-valid due to some activities, maintenance activities on the device

Off-specification – S
• The Device operates out of the specified measurement range
• Internal diagnostics in the device indicates a drift in the measurement (internal problems in the device or consequence of some process influence (cavitation, empty pipe, ...)).
## NAMUR recommendations

### Diagnostic symbols (NE 107)

<table>
<thead>
<tr>
<th>Status</th>
<th>Symbol 1</th>
<th>Symbol 2</th>
<th>Symbol 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance required</td>
<td><img src="image" alt="Blue symbol" /></td>
<td><img src="image" alt="Icon 1" /></td>
<td><img src="image" alt="Icon 2" /></td>
</tr>
<tr>
<td>Out of specification</td>
<td><img src="image" alt="Yellow symbol" /></td>
<td><img src="image" alt="Icon 3" /></td>
<td><img src="image" alt="Icon 4" /></td>
</tr>
<tr>
<td>Check function</td>
<td><img src="image" alt="Orange symbol" /></td>
<td><img src="image" alt="Icon 5" /></td>
<td><img src="image" alt="Icon 6" /></td>
</tr>
<tr>
<td>Failure</td>
<td><img src="image" alt="Red symbol" /></td>
<td><img src="image" alt="Icon 7" /></td>
<td><img src="image" alt="Icon 8" /></td>
</tr>
<tr>
<td>Diagnostics active</td>
<td><img src="image" alt="Green symbol" /></td>
<td><img src="image" alt="Icon 9" /></td>
<td><img src="image" alt="Icon 10" /></td>
</tr>
<tr>
<td>Diagnostics passive</td>
<td><img src="image" alt="Gray symbol" /></td>
<td><img src="image" alt="Icon 11" /></td>
<td><img src="image" alt="Icon 12" /></td>
</tr>
</tbody>
</table>

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Detailed Device Diagnostics

e.g. Process Automation, Asset Management, Data Acquisition

HART / PROFIBUS / FOUNDATION Fieldbus

Detailed Diagnostic Events
Condensed Status and Diagnostics

- **Maintenance Required**
- **Failure**
- **Functional Check**
- **Out of Specification**

E.g. Process Automation, Asset Management, Data Acquisition

HART / PROFIBUS / FOUNDATION Fieldbus
NAMUR recommendations

**Instrument diagnostics**
e.g. SIL certified devices
(IEC 61508/61511)

**Application diagnostics (NE 107)**
e.g. Coriolis mass flow meter
Gas bubbles in the liquid, fouling, clogging, erosion, corrosion, faulty mounting, external vibrations, pulsating flow, incomplete filling

Application diagnostics are defined for flow -, level -, pressure -, temperature measurements and control valves
NAMUR recommendations

Application diagnostics (NE 107)

Example: mass flowmeter

Coriolis mass flow meter
- Gas bubbles in the liquid
- Fouling, clogging
- Erosion, corrosion
- Faulty mounting
- Asymmetry of measuring tubes (dual tube only)
- External vibrations
- Pulsating flow
- Incomplete filling

Connect diagnostic to one status signal
Live demonstration
Relevant FOUNDATION Technologies

• Block Based Architecture
  • Represent basic automation functions
  • Fully distributed architecture
  • Profiles provide minimum device specifications
  • Enables Control in the Field
  • Provides for single loop integrity

• Interrupt Driven Alarm Model
  • Alarms are pushed by device; no polling required and therefore enhances network efficiency
  • Alarms can be directed to any station
  • Timestamps at the device
Standard Diagnostic Profile

Field Diagnostics Profile (FF-912):

• Provide a standard and open interface for reporting all device alarm conditions
• Provide a means to categorize alert conditions by severity
• Facilitates routing of alerts to appropriate user consoles
• Severity category can be selected by the end-user
• Provide recommended corrective action and detailed help
• Provide an indication of the overall health of the device
Block Based Architecture

Today a device architecture includes:

- One Resource Block for Identification
- One or More Transducer Blocks
  - Device Configuration
  - Diagnostics
  - Maintenance
- One or more Function Blocks
  - Monitoring (e.g. Analog Input)
  - Control (e.g. Analog Output, PID Control)
FF Alarms associated with block types

- Alarms related to the process (e.g. HI_ALM)
- Alarms related to the device (e.g. BLOCK_ALM)

<table>
<thead>
<tr>
<th>Alarm Type</th>
<th>Relation</th>
<th>Failure Type</th>
</tr>
</thead>
</table>
| Process Alarm    | Process / Environment | Process failures  
Faults in the process                                                   |
| Device Alarm     | Instrument       | Sensor/Actuator element failures  
Faults in the sensor or actuator element                                |
|                  | Process / Environment | Electronic failures  
Faults in the electronics                                             |
|                  |                  | Configuration/servicing failures  
Installation faults, fault during start-up                           |
|                  |                  | Process induced failures  
Faults due to process influence  
Faults due to non-compliance with specified operating conditions |
Concept Overview

Increasing Priority at device level
Manufacturer Specific Conditions
32 bit Bitstring

User defined

User defined

Manufacturer defined

SD_RECOMMENDED_ACTION

DS87
Standard Diagnostic Alarms

- Foundation Fieldbus devices will have 4 standard device alarms
- Alarms map directly to Status Signals

<table>
<thead>
<tr>
<th>FF Standard Diagnostic Alarm</th>
<th>NE107 Status Signal (5.1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD_FAIL_ALM</td>
<td>Failure</td>
</tr>
<tr>
<td>SD_OFFSPEC_ALM</td>
<td>Out of Specification</td>
</tr>
<tr>
<td>SD_MAINT_ALM</td>
<td>Maintenance Request</td>
</tr>
<tr>
<td>SD_CHECK_ALM</td>
<td>Function Check</td>
</tr>
</tbody>
</table>
Configuration Parameters

- Each alarm is user configured with the following parameters:

<table>
<thead>
<tr>
<th>Function</th>
<th>Supporting Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map Manufacturer Specific diagnostic to Device Alarm</td>
<td><em>__ENABLE</em></td>
</tr>
<tr>
<td>Enable/Disable Manufacturer Specific diagnostic to trigger Device Alarm</td>
<td><em>__MASK</em></td>
</tr>
<tr>
<td>Configure Device Alarm Priority</td>
<td><em>__PRI</em></td>
</tr>
</tbody>
</table>
Diagnostic Information

- The following items provide information about the current diagnostics.

<table>
<thead>
<tr>
<th>Function</th>
<th>Parameter/Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Show current active alarms</td>
<td><em>__ACTIVE</em></td>
</tr>
<tr>
<td>Recommended action to resolve diagnostic</td>
<td>SD_RECOMMENDED_ACTION</td>
</tr>
</tbody>
</table>
Resource Block Extension

All new parameters will be added to the standard Resource Block.

<table>
<thead>
<tr>
<th>Parameter Mnemonic</th>
<th>VIEW_1</th>
<th>VIEW_2</th>
<th>VIEW_3</th>
<th>VIEW_4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD_REV</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>SD_FAIL_ACTIVE</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD_OFFSPEC_ACTIVE</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD_MAINT_ACTIVE</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD_CHECK_ACTIVE</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD_FAIL_ENABLE</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>SD_OFFSPEC_ENABLE</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>SD_MAINT_ENABLE</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>SD_CHECK_ENABLE</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>SD_FAIL_MASK</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD_OFFSPEC_MASK</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD_MAINT_MASK</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD_CHECK_MASK</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD_FAIL_ALM</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SD_OFFSPEC_ALM</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>SD_MAINT_ALM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD_CHECK_ALM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD_FAIL_PRI</td>
<td></td>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>SD_OFFSPEC_PRI</td>
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<td>1</td>
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<tr>
<td>SD_MAINT_PRI</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>SD_CHECK_PRI</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>SD_RECOMMENDED_ACTION</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Concept Overview

ALARM BROADCAST RECORD
- SD_FAIL_ALM
- SD_OFFSPEC_ALM
- SD_MAINT_ALM
- SD_CHECK_ALM

ALARM BROADCAST ENABLE
- SD_FAIL_PRI
- SD_OFFSPEC_PRI
- SD_MAINT_PRI
- SD_CHECK_PRI

ALARM INDICATION (POLLING)
- SD_FAIL_ACTIVE
- SD_OFFSPEC_ACTIVE
- SD_MAINT_ACTIVE
- SD_CHECK_ACTIVE

ALARM DETECTION ENABLE
- SD_FAIL_ENABLE
- SD_OFFSPEC_ENABLE
- SD_MAINT_ENABLE
- SD_CHECK_ENABLE

User defined Bitstring 32 bits

User defined Bitstring 32 bits

Manufacturer defined

DS87

SD_RECOMMENDED_ACTION
# Grouping Diagnostics Conditions

## Manufacturer Specific Diagnostic Conditions (100s)

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>121</td>
<td>Checksum Error in factory segment of EEPROM A121</td>
</tr>
<tr>
<td>131</td>
<td>Checksum error in EEPROM: minMAX segment A131</td>
</tr>
<tr>
<td>132</td>
<td>Checksum Error in Totalizer EEPROM A132</td>
</tr>
<tr>
<td>133</td>
<td>Checksum Error in History EEPROM A133</td>
</tr>
<tr>
<td>702</td>
<td>HISTOROM data not consistent, V702</td>
</tr>
<tr>
<td>706</td>
<td>Configuration in HISTOROM and device not identical, V706</td>
</tr>
<tr>
<td>743</td>
<td>Electronic PCB error during initialization, A743</td>
</tr>
<tr>
<td>748</td>
<td>Memory failure in signal processor, A748</td>
</tr>
<tr>
<td>602</td>
<td>Linearizations curve not monotonic, V602</td>
</tr>
<tr>
<td>604</td>
<td>Linearisation table not valid, At least 2 points, V604</td>
</tr>
<tr>
<td>620</td>
<td>Current output out of range, E620</td>
</tr>
<tr>
<td>700</td>
<td>Last Configuration not stored, V700</td>
</tr>
<tr>
<td>703</td>
<td>Measurement error, A703</td>
</tr>
<tr>
<td>704</td>
<td>Measurement error, A704</td>
</tr>
<tr>
<td>705</td>
<td>Measurement error, A705</td>
</tr>
<tr>
<td>707</td>
<td>X-VAL of lin. table out of edit limits A707</td>
</tr>
<tr>
<td>710</td>
<td>Set span too small Not allowed, V710</td>
</tr>
<tr>
<td>711</td>
<td>LRV or URV out of edit limits, A711</td>
</tr>
<tr>
<td>713</td>
<td>100% POINT level out of edit limits A713</td>
</tr>
<tr>
<td>719</td>
<td>Y-VAL of lin. table out of edit limits A719</td>
</tr>
<tr>
<td>721</td>
<td>EMPTY CALIB; or FULL CALIB; out of edit limits A721</td>
</tr>
<tr>
<td>723</td>
<td>MAX. FLOW out of edit limits, A723</td>
</tr>
<tr>
<td>730</td>
<td>LRV user limits exceeded, E730</td>
</tr>
<tr>
<td>731</td>
<td>URV user limits exceeded, E731</td>
</tr>
<tr>
<td>732</td>
<td>LRV-Temp. User limits exceeded, E732</td>
</tr>
<tr>
<td>733</td>
<td>URV-Temp. User limits exceeded, E733</td>
</tr>
<tr>
<td>737</td>
<td>Measurement error, A737</td>
</tr>
<tr>
<td>738</td>
<td>Measurement error, A738</td>
</tr>
<tr>
<td>739</td>
<td>Measurement error, A739</td>
</tr>
<tr>
<td>741</td>
<td>TANK HEIGHT out of edit limits A741</td>
</tr>
<tr>
<td>101</td>
<td>Sensor electronic EEPROM error, A101</td>
</tr>
<tr>
<td>115</td>
<td>Sensor overpressure, E115</td>
</tr>
</tbody>
</table>

## Manufacturer Grouped Diagnostics (32)

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Function Check</td>
</tr>
<tr>
<td>24</td>
<td>Clogged pressure sensor</td>
</tr>
<tr>
<td>25</td>
<td>Pressure sensor range</td>
</tr>
<tr>
<td>26</td>
<td>Pressure sensor failure</td>
</tr>
<tr>
<td>27</td>
<td>Thermocouple value outside sensor range</td>
</tr>
<tr>
<td>29</td>
<td>Thermocouple failure</td>
</tr>
<tr>
<td>29</td>
<td>Power Supply failure</td>
</tr>
<tr>
<td>30</td>
<td>Ram memory failure</td>
</tr>
<tr>
<td>31</td>
<td>Flash memory failure</td>
</tr>
</tbody>
</table>
### Diagnostic Mapping Workflow

#### Device Diagnostics (defined by Manufacturer)

<table>
<thead>
<tr>
<th>0</th>
<th>Function Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>24</td>
<td>Clogged pressure sensor</td>
</tr>
<tr>
<td>25</td>
<td>Pressure sensor range</td>
</tr>
<tr>
<td>26</td>
<td>Pressure sensor failure</td>
</tr>
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<td>27</td>
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</tr>
<tr>
<td>31</td>
<td>Flash memory failure</td>
</tr>
</tbody>
</table>

#### Diagnostic Profile Parameters (configured by User)

- **SD_CHECK_ENABLE/MASK**
  - Function Check

- **SD_MAINT_ENABLE/MASK**
  - Clogged pressure sensor
  - Thermocouple failure
  - Flash memory failure
  - Power Supply failure
  - Pressure sensor failure

- **SD_OFFSPEC_ENABLE/MASK**
  - Thermocouple value outside sensor range
  - Pressure sensor range

- **SD_FAIL_ENABLE/MASK**
  - Thermocouple failure
  - Flash memory failure
  - Power Supply failure
  - Pressure sensor failure

Each diagnostic can map to zero or more alarms. Manufacturer provides default values.