Device Diagnostics Deployment and Adoption Guide

Institutionalizing Device Diagnostics in Daly Maintenance

Many operation and maintenance problems around the plant can be solved by deploying intelligent devices and IDM software. However, regardless of communication protocol, plant procedures must be written so as to make full use of the device diagnostics. Furthermore, the device alarm management must be engineered, and the IDM software must be kept up to date with new device types and versions as they arrive in the plant. With the hardware, software, and standard operating procedures in place, effective use of device diagnostics is possible. That is, device diagnostics must be institutionalized in daily work processes to be effective.

Most plants already have intelligent devices with self-diagnostics, but it is not utilized. This is a guide to institutionalizing device diagnostics in daily work processes.

1 Glossary

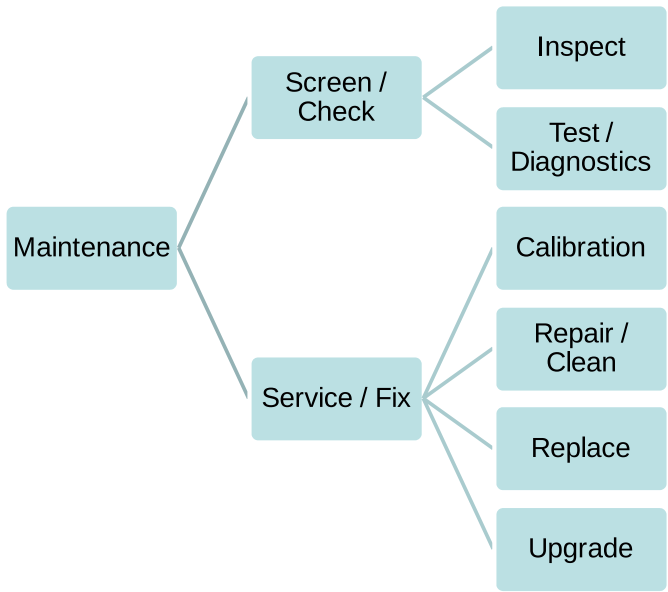
Just like any technology, intelligent device management has its own set of terminology and acronyms

1.1 Terminology

Device Management	Configuration/setup, sensor calibration trim, and diagnostics etc. of field devices.
Unscheduled communication	Non-real-time communication such as setpoint or mode change, configuration or firmware download, and detailed diagnostics etc. A.k.a. background traffic [FOUNDATION fieldbus]
Scheduled communication	Real-time, time synchronized precisely periodic communication such as process variable and output, with status. Slightly different from cyclic [FOUNDATION fieldbus]
Cyclic communication	Real-time, periodic communication such as process variable and output. Slightly different from scheduled [PROFIBUS]
Acyclic communication	Non-real-time communication such as setpoint or mode change, configuration download, and detailed diagnostics etc. [PROFIBUS]
Background traffic	See unscheduled communication
Device Template	Configuration file containing the preferred generic configuration settings for a device type
Turnaround	Scheduled plant shutdown when a plant is stopped for an extended period for major overhaul. A.k.a. outage.
Ticket	Electronic work order for a job to be carried out
Intelligent Device	Device having a microprocessor and digital communication
Alert	Collective term for alarms and events

In this document the terms "work order" (usually on paper) and "ticket" (electronic) are used interchangeably.

The term "remote" refers to the field or plant floor, while the term "central" refers to the control room or LER as opposed to the field or plant floor.



1.2 Acronyms

AMS	Asset Management System
CMMS	Computerized Maintenance Management System
DCS	Distributed Control System
DD	Device Description (old abbreviation and term, now replaced by EDDL-file)
EDDL	Electronic Device Description Language
FAR	Field Auxiliary Room
FAT	Factory Acceptance Test
FEED	Front-End Engineering & Design
HART	Highway Addressable Remote Transducer
HMI	Human-Machine Interface
IDM	Intelligent Device Management
LER	Local Equipment Room
PAM	Plant Asset Management
PIB	Process Instrument Building
PLC	Programmable Logic Controller
RCA	Root Cause Analysis
RCM	Reliability Centered Maintenance
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
SIS	Safety Instrumented System
SRR	Satellite Rack Room

In this document the terms "Local Equipment Room" (LER), "Field Auxiliary Room" (FAR), "Process Instrument Building" (PIB), and "Satellite Rack Room" (SRR) are used interchangeably.

2 Introduction

IDM is an engineered solution, and implementation of IDM is a project. Implementation will have associated engineering hours and cost regardless of the protocols used. The basic implementation phases are illustrated in figure 1 and explained in table 1.

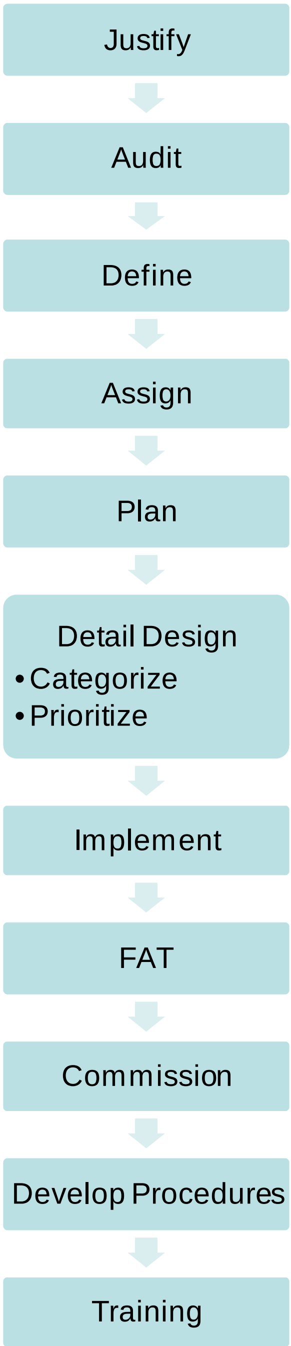


Figure 1 Basics steps in implementing IDM

There will be minor differences depending on if the project is for an existing plant or a new plant being constructed.

Table 1 Basics steps in implementing IDM

Section	Phase	Description
3	Justify	Explain the value of IDM to obtain management buy-in, funding ,and other resources
4	Audit	Asses existing system architecture to identify requirements to support IDM
5	Define	Establish project scope and system architecture needs as a basis for design
6	Assign	Name those responsible for project execution and continued use of IDM
7	Plan	Planning of the system deployment including training, changes

Section	Phase	Description
		in job scopes, resources required, and changes in procedures
8 8.2 8.3	Detail Design • Categorize • Prioritize	 Categorize device diagnostics alarms for each device type Identify criticality to the process for each device tag
9	Implementation	Build database configuration for system and devices based on detail design alarm management and reports
10	FAT	Factory Acceptance Test (FAT) to verify correct system configuration for alarm management and reports
11	Commissioning	Tuning of device diagnostics to fit the application
12	Develop Procedures	Rewrite maintenance procedures to include the IDM software
13	Training	Customized training for project team, system engineers, commissioning team, and maintenance technicians

3 Justification

The initial step is to get buy-in from the plant management. For an existing plant, there is a need to justify the addition of IDM. For a new plant the inclusion of IDM as part of the project must be justified

Explain to the plant management, instrument lead, control system lead, maintenance manager, and project/turnaround manager the opportunity to improve maintenance using IDM and the value of having IDM software. Investment in intelligent devices and centralized IDM software can be justified on the basis of reduced downtime and lower cost of maintenance etc. provided the device diagnostics is institutionalized in the daily work processes and the plant culture. If the metrics for the plant's percentage of reactive, periodic preventive and predictive maintenance is known, this can be contrasted against industry best practice.

3.1 Opportunity

Plants face a number of operational and maintenance challenges related to instrumentation and valves. These challenges and the capabilities required to tackle those problems as well as the expected result are summarized in Table 2.

Table 2 IDM opportunity summary

Plant Challenge	IDM Capability	Result
Instruments and valves are underperforming because they have not been calibrated or adjusted for a long time, resulting in off-spec product, inefficient operation, or high energy consumption etc.	Ability to centrally diagnose if a device <u>needs</u> calibration or adjustment	Devices performing at their best, reducing process variability, resulting in higher quality/yield and ability to move setpoint closer to ideal for higher throughput and lower energy consumption
Operators disbelieving devices, suspecting failure, call out technicians to inspect instrumentation in the field; they test and calibrate only to find nothing wrong, the device is healthy	Process variable status for operators and ability to centrally diagnose if a device does <u>NOT need</u> service, may instead be process behaving unexpectedly	Don’t have to send technician to the field unnecessarily, freeing up technicians to service devices that need repair. Going to the field is an exception
Long device repair time prolonging process downtime, reducing	Ability to centrally diagnose what service the device requires	Bring right tools and spares to the field to fix it quicker, increasing availability

Plant Challenge	IDM Capability	Result
availability		
Device problems masquerading as process problems (20 mA) cause spurious shutdown by control strategy	Control strategy ability to in real-time distinguish a device problem from a process problem	Operator is alarmed but control strategy does not shut down loop on a device problem thereby increasing availability
Devices run until failure causing process downtime because signs of trouble go undetected; reactive maintenance	Ability to centrally diagnose and predict device failure before it actually fails	Degraded devices are scheduled for maintenance before they fail thereby avoiding downtime
Undetected device failure cause product to go out of spec.	Early detection and central notification of device failure to operator provides ability to quickly tend process	Operator can avoid a device failure from causing excessive amounts of off-spec product or cause shutdown, thus improving quality/yield and availability
Calibration of all transmitters and tear-down of all valves at turnarounds to remain compliant and reduce risk, many with no problems found, is a waste of time and resources; periodic preventive maintenance	Ability to centrally diagnose and screen devices while the plant is running to determine which devices require calibration, tear-down, or other servicing to plan and optimize the turnaround schedule	Minimize scope of turnaround inspection, test, and calibration to save resources and shorten the duration of the turnaround outage, resulting in lower maintenance cost
Frequent device type-specific or plant location-specific failure patterns are not recognized	Ability to recognize patters in device types or plant locations with high failure rate	Eliminate bad actors, thus reducing both downtime and maintenance cost
Remote locations have no onsite maintenance technicians, making the above challenges even more acute	Ability for expert to diagnose problems at remote sites from a central location	Eliminate multiple troubleshooting visits to remote site, thus reducing maintenance cost

Self-diagnostics in intelligent devices in conjunction with central IDM software can provide these capabilities when institutionalized in daily work processes.

3.2 *Ability and Result*

By deploying intelligent devices with centralized IDM software, institutionalized in daily work processes plants can reduce downtime and maintenance cost.

3.2.1 Ability to diagnose if the device needs calibration or adjustment

Many transmitters, flowmeters, and analyzers around existing plants are out of calibration but nobody knows which ones. Similarly, some of the control valves may be hunting due to incorrect tuning of the positioner.

Device self-diagnostics can detect when instruments or valves need servicing and notify maintenance technicians centrally in the workshop which can schedule servicing at a convenient time. For instance detect if pH sensor or flowmeter is likely to have drifted out of calibration, or if the valve is hunting. A temperature transmitter can detect when the temperature sensor has drifted and needs replacing.

That is, device diagnostics when institutionalized in daily work processes can be used to help ensure devices are performing at their best, ensuring on-spec product, more efficient operation, and lower energy consumption etc.

3.2.2 Ability to diagnose a device does not need service

In a typical plant, far too often instrument technicians are called out to inspect instrumentation in the field, only to find there is nothing wrong with it.

By instead checking the device's self-diagnostics centrally from the IDM software before going to the field, technicians can tell if going to the field is really required or not. For example, it is possible to tell if the transmitter or sensor etc. are healthy or have failed have to be replaced etc.

That is, device diagnostics when institutionalized in daily work processes can be used to reduce the number of times technicians have to go to the field, saving time and resources which is better spent on devices which actually need service.

3.2.3 Ability to diagnose what service the device requires

When a device fails the technician does not know what the problem is, arriving at the device without much preparation, and without the proper tools and spares. The technician may have to return to the workshop to get it, prolonging the downtime, or may replace the whole transmitter.

By instead checking the device's self-diagnostics centrally from the IDM software before going to the field, technicians can pin-point the probable cause, see recommended action, and bring the correct tools and spares to fix the problem quicker.

That is, device diagnostics when institutionalized in daily work processes can be used to reduce downtime due to instrument failure, and to make the most efficient use of the technician's time.

3.2.4 Control strategy ability to distinguish a device problem from a process problem

In case of a sensor or device failure a transmitter with 4-20 mA signal will set its output to 20 mA (or 4 mA in some applications), masquerading as a high process variable, causing the loop to shutdown even though there is nothing wrong with the process.

Process variable status, derived from device self-diagnostics, communicated in real-time together with the process variable can be used by the control strategy to distinguish a device problem such as a sensor failure from a process problem such as high pressure or temperature. Loops can now configured to go to manual mode in this case and centrally alarm the operator. On this alarm the operator can first take action to take care of the process, and then inform maintenance technicians to fix the device. The loop can optionally be configured to shut down on device failure. Moreover, the status gives operators greater confidence in the validity of the measurement.

This functionality requires real-time digital communication of process variable status together with the value. FOUNDATION fieldbus and PROFIBUS-PA meet this requirement. It is also required that the process variable status is supported in the DCS controller function blocks.

That is, device diagnostics when utilized in the control strategy can reduce downtime due to instrument failure.

3.2.5 Ability to diagnose and predict device failure before it actually fails

Usually devices are allowed to run until they fail. The device failure in turn causes the process to shutdown resulting in downtime.

A temperature transmitter can detect not only when a thermocouple has failed, but the early signs when it is thinning before failure. A valve positioner can detect when a valve stem packing needs replacing due to wear and tear etc. That is, these are examples of predictive alarms before the device actually fails. Device diagnostics alarm monitoring capture these alarms and centrally notifies the maintenance technicians that can order the required spares and schedule maintenance at a convenient time.

That is, device diagnostics when institutionalized in daily work processes can be used to detect degradation early and service before failure materializes thus reducing downtime from a major unplanned shutdown to a minor scheduled outage.

3.2.6 Operator ability to quickly tend process when device fails

A failed device may within hours or minutes cause sequential logic for a batch operation to stop, ruining an entire batch, or may cause a control loop to malfunction making the product out of spec. Such device failures may go unnoticed until the quality control department detects a problem with the product by which time raw material and energy has been wasted, and product has to be disposed of or reworked.

Device self-diagnostics detect failures almost instantly. Depending on the architecture, the networking can quickly communicate the diagnostics to the system operator consoles where the diagnostics can be viewed centrally by the operators. Thus operators may have minutes or hours of early warning, enough time make changes before the process is affected by the device failure. The operator will first take care of the process, and then call upon the maintenance technician to fix the device.

That is, device diagnostics when institutionalized in daily work processes can be used to avoid shutdowns and to fix device problems sooner.

Early warning to operators of impending process problems resulting from device failure requires fast device alarm monitoring to quickly communicate the diagnostics from the device to the system. For plants using 4-20 mA/HART devices, the polling time to report the diagnostics depends on the system architecture. In a system with centralized software polling devices one-by-one, the time to poll all devices can be more than an hour. Newer systems have HART polling decentralized. A microprocessor in the 4-20 mA/HART I/O card polls the HART devices connected to that card (8, 16, or 32 channels) and use report by exception to communicate device problems to the system software in less than a minute depending on the number of I/O channels in the card. For FOUNDATION fieldbus and PROFIBUS the diagnostics is reported within seconds.

Early warning to operators of impending process problems resulting from device failure also require diagnostics display integrated in the DCS operator console. Since third-party software is not allowed on a DCS in order to ensure the system remains robust, driver software components from the device manufacturers cannot be used. However, IDM software based on EDDL (a compressed text file, no executable software) is permitted on the DCS.

3.2.7 Ability to diagnose which devices to calibrate and tear-down at turnaround

At periodic plant shutdown in the past, preventive check and calibration was done on all devices, even removing valves and tearing them down. Many of them did not need it. This was a waste of resources.

A flowmeter with meter verification can be checked centrally if calibration is required. A positioner on a control valve be checked centrally if the valve has to be pulled and torn down for repair. This makes it possible to better schedule the plant shutdown.

That is, device diagnostics when institutionalized in daily work processes can be used to reduce preventive maintenance and schedule the plant turnaround shutdown more effectively.

F1 Pit-Stop

An analogy can be made between device maintenance and Formula 1. An F1 car has sensors and a telemetry system to report the health back to the pit crew. This information is used to decide if the car needs to make a pit-stop for servicing or can continue until the end of the race without downtime improving the chances to win. The data also tells the pit crew what service the car needs and what it does not need so the pit crew can prepare all the parts and crew to tend to the problem in the shortest possible time, not wasting time on non-issues, minimizing downtime, as well as preventing a breakdown before the finish line is crossed.

Similarly, an ideal plant has sensors and networking to report the health back to the operators and technicians. This information is used to decide if the unit needs to be shutdown to service a device or can continue production until the next scheduled turnaround without downtime maintaining the output. The data also tells the maintenance technicians what service the device needs and what it does not need so the maintenance technicians can prepare all the parts and manpower to tend to the problem in the shortest possible time, not wasting time on non-issues, minimizing downtime, as well as preventing a breakdown before the scheduled turnaround.

4 Audit Existing Plant

For an existing plant to deploy IDM it necessary to audit the system hardware and software as well as devices and technology to identify shortcomings which need to be filled before work practices based on device diagnostics can be adopted. The plant may have all the hardware, and all the software required, but it is very common that the device alarm categorization, prioritization, and configuration has not been done and that procedures have not been rewritten. The audit is an opportunity to rate plant's IDM readiness. It is necessary to work closely with the systems lead and instrumentation lead to get the details of the devices installed such as which digital communication protocols they are using, types, and versions etc. similarly it is necessary to know versions of software and hardware, if the system has native support for these protocols, if multiplexers, or gateways etc. are used, and lastly what specific software is being used with devices. The assessment should also include a look at the current work processes and procedures, as well as the maintenance regime, culture, and the skills of the plant staff.

5 Define System Architecture

The IDM project scope has to be defined early on in the project involving the project/urnaround team, the control systems team, instrumentation team, system supplier, and the maintenance group. It should be documented in a form of basis of design, a functional design specification including system architecture, protocols to be used, hardware and software, as well as associated services. For an existing plant the system architecture requirements based on the plant audit and gap analysis. IDM is an engineered solution, and implementation of IDM is a project. Make sure to include cost of engineering man-hours in project scope of work and in the budget.

5.1 New Plant FEED

At the FEED stage a new plant being built can choose the system architecture that gives the best possible support for diagnostics from as many of the intelligent devices as possible. Note that a system architecture capable of IDM is possible not only for DCS, but also for RTUs in remote (SCADA) applications such as unmanned platforms, oil fields, and pipelines etc. Indeed hard to access sites probably benefit the most from device self-diagnostics and centralized IDM.

By defining the scope of work associated with IDM, the EPC contactor and system supplier can better estimate the number of engineering hours required.

5.2 Existing Plant

An existing plant cannot choose their system architecture. They've got what they've got. What existing plants can do with what they have, if they are completely replacing the control system, is to study what has to be added to the system to deploy centralized IDM software. In most plants with 4-20 mA/HART devices, the control system use only the 4-20 mA signal. HART communication is only used for commissioning with a handheld field communicator. The diagnostics from the devices is often not utilized. In many plants with FOUNDATION fieldbus, the communication is used for real-time closed loop control but the diagnostics not fully utilized.

5.3 Network Protocols

Intelligent devices are available with many different protocols such as HART (for 4-20 mA devices), WirelessHART, FOUNDATION fieldbus, PROFIBUS-DP, and PROFIBUS-PA, ASi, DeviceNet, and Modbus. Process instrumentation tends to use 4-20 mA/HART, WirelessHART, FOUNDATION fieldbus, or PROFIBUS-PA. On/off devices tend to use ASi or FOUNDATION fieldbus. Electrical equipment tend to use PROFIBUS-DP or DeviceNet. Safety transmitter use 4-20 mA for safety with superimposed HART protocol. Safety shutdown valve solenoid use an on/off signal without digital communication (additionally a Partial Stroke Testing device may use 4-20 mA/HART). No kind of device is available in versions for all these protocols and no protocol is used in every kind of device. Therefore it is necessary to use more than one protocol in the plant.

Table 3 Device and protocol availability

	HART	ASI	DN	MB	DPv1	PA	FF-H1
Transmitter / Analyzer / Meter	Y	-	-	-	-	Y	Y
Control valve positioner	Y	-	-	-	-	Y	Y
Electric actuator / MOV	-	-	-	-	Y	-	Y
On/Off valve (process)	-	Y	Y	-	-	-	Y
Proximity switches	-	Y	Y	-	-	-	-
Solenoids	-	Y	Y	-	-	-	-
I/O block	-	-	Y	Y	Y	-	Y
Motor starters	-	-	Y	Y	Y	-	-
Drives	-	-	Y	Y	Y	-	-
SIS transmitter (4-20 mA)	Y*	-	-	-	-	-	-
SIS on/off valve partial stroke tester (discrete on/off signal)	Y**	-	-	-	-	-	-
Gas chromatograph	-	-	-	Y	-	-	Y
Tank gauging system	-	-	-	-	-	-	Y

*/** Note: Safety function uses 4-20 mA and on/off signal, not the

5.3.1 IDM Information

Not all protocols support unscheduled/acyclic non-real-time communication for setup information and diagnostics. Such protocols carry only scheduled/cyclic real-time communication such as sensor inputs and actuator outputs, which is sufficient to reduce wiring cost using multi-drop connection and multiple variables per device such as valves but does not enable IDM and the associated maintenance. Therefore make sure to select protocols that support acyclic/unscheduled communication of setup and diagnostics information.

EDDL is required by the system device alarm management to make the configuration of alarm filtering easy. EDDL is also the preferred solution for displaying device diagnostics and setup information (see separate white paper on ease of use). However, not all protocols support EDDL. Therefore make sure to use protocols that support EDDL.

Table 4 Protocol features

	HART	ASI	DN	MB	DPv1	PA	FF-H1
Cyclic I/O	4-20 mA	✔	✔	✘	✔	✔	✔
Acyclic data acquisition (setup/diagnostics)	✔	✘	✔	✔	✔	✔	✔
EDDL	✔	✘	✘	✘	✔	✔	✔

5.3.2 Caveat Emptor: Proprietary Protocols

Devices are also available with a multitude of proprietary protocols. For instance, electric actuators (MOV), tank gauging systems, and gas chromatographs often use proprietary protocols. Proprietary protocols are able to bring diagnostics to proprietary software but not into common IDM software.

Even though drivers and software can be used to access data in a proprietary device, interface hardware still becomes a lock-in since other devices cannot share the same bus. Therefore standard protocols shall always be the first choice.

Proprietary protocols have many downsides and should therefore be avoided:

- Single vendor lock-in
- Requires its own dedicated bus
- No second source replacement devices
- Requires special training and test tools
- Requires intermediate gateway to Modbus
- Requires additional system configuration to map and display I/O and diagnostics
- Requires special configuration software

If the plant is using devices with proprietary protocols, replace those devices with devices using standard protocols.

5.4 Intelligent Devices

Device self-diagnostics can be divided into two classes: continuous and on-demand.

Continuous self-diagnostics runs autonomously entirely onboard (inside) the device all the time without user request. Continuous self-diagnostics is non-intrusive, not affecting the process. Examples of continuous self-diagnostics include:

- Performance diagnostics inside a valve positioner
- Electrode signal fault in magnetic flowmeter
- Thermocouple degradation detection in a temperature transmitter
- Statistical process monitoring in a pressure transmitter

On-demand diagnostics only runs when requested by the technician. On-demand is used if the diagnostics affect the process (requiring process shutdown or bypass), or if the device is not capable of processing the sensor data, but only collect raw data from onboard sensors which require analysis in computer software. That is, on-demand diagnostics is not continuous. There must be a procedure in place for technicians to schedule and periodically run such diagnostics. On-demand diagnostics include:

- Meter verification in a Coriolis mass flow meter
- Valve signature in a valve positioner

5.4.1 Actionable Information

It is important that software not just display device error messages, but instead provide advise which maintenance technicians can act upon. The device manufacturer must provide an EDDL file which provides guidance for the device diagnostic alarms to make them:
Understandable: Provide a clear message that is easily understood, not a cryptic code
Diagnostic: Helps with the identification of the problem
Advisory: Provides guidance towards the correct action
Focusing: Directs attention to the important aspects

From Data to Actionable Information

The original promise of intelligent devices and digital communication was to bring diagnostics to the maintenance workshop and control room. 4-20 mA/HART, FOUNDATION fieldbus, and PROFIBUS etc. all delivered on this promise by being able to display diagnostics such as “Error 13”. However, nobody understood what it meant or what had to be done so this data was useless. Thanks to advances with enhanced EDDL, many devices are now displayed with actionable information; explaining the problem and proposed actions in plain text and with illustrations.

5.4.2 Selecting Intelligent Devices

Select devices using standard protocols such as HART, FOUNDATION fieldbus, PROFIBUS-DP, and WirelessHART. Avoid proprietary protocols.

5.4.3 Self-Diagnostics

The extent of self-diagnostics provided by devices varies greatly. It depends on if the device is high-end or low-cost, and varies greatly from one manufacturer to the next. Multiple tiers of self-diagnostics sophistication may also be licensed at different cost. For two-wire devices self-diagnostics capability even depends on the protocol used (the amount of power provided over the two wires).

Make sure to specify the required diagnostics when requesting quotations. When placing order, specify the model code in case advanced diagnostics is an option.

5.4.4 User Interface

Ultimately when device self-diagnostics detects a problem, the technician must know what to do to rectify this problem. Therefore, select device which not only provides extensive self-diagnostics, but for which the device developer also provides an intuitive user interface, guiding the technician to the possible causes, and recommending actions to fix the problem. Make sure the device is provided with an EDDL file according to the IEC 61804-3 standard, providing enhanced graphics, wizards (methods) for calibration and setup, makes use of conditionals to only request required information, and only display valid options, and applicable illustrations. For FOUNDATION fieldbus devices, 'device level access' (DD v 5.1) should be used to group diagnostics together regardless of block location.

5.4.5 Re-instrumentation

In an existing plant with an installed base of devices:

- Replace non-smart 4-20 mA transmitters and positioners to 4-20 mA/HART. It can be part of natural replacement as transmitters fail, or can focus critical valves.
- Replace intelligent 4-20 mA transmitters using proprietary smart protocols to 4-20 mA/HART. Start with critical or challenging measurements that benefit the most from device self-diagnostics.
- Upgrade or replace devices like electric actuators (MOV), gas chromatographs, and tank gauging systems etc. using proprietary protocols or Modbus to 4-20 mA/HART, FOUNDATION fieldbus, or PROFIBUS. There is an opportunity to meet new requirements for accuracy and functional safety at the same time.

5.5 IDM Software

Both *device configuration software* and *IDM software* are used to configure and diagnose intelligent devices, including calibration[1]. The difference is:

Table 5 Software features

	IDM Software	Device Configuration Software
Device configuration	Yes	Yes
Device configuration management (Audit trail)	Yes	No
Device diagnostics	Yes	Yes
Continuous device diagnostics monitoring and alarm management	Yes	No
Calibration	Yes	Yes
Calibration management (scheduling)	Yes	No
Simultaneous users	Multi-user	Single
Architecture	Client-server networked system	Stand-alone
Instrument database	Yes	No
Computer (typical)	Workstations	Laptop
Location	Fixed, central	Portable, workshop or field
Device connection	Permanent network infrastructure, always on	Temporary, ad-hoc, interface clip-on leads

Device configuration software is a stand-alone application, usually on a laptop, connected temporarily on the workbench or in the field using a portable interface, for as-hoc device diagnostics interrogation or configuration as and when a problem is already suspected. That is, it is used very similar to a handheld field communicator.

Similar to a handheld field communicator, configuration software on a laptop with interface complements central IDM software.

Note that a handheld field communicator is still very useful for work in the field, in that it can be held in one hand while operated by the other, can be used in hazardous areas, has very long battery life, and is extremely rugged. Make sure the plant has handheld field communicators available.

IDM software typically is a client-server system supporting multiple simultaneous users, often part of a larger Asset Management System (AMS). It includes an device diagnostic monitor function which continuously queries the field devices for their self-diagnostics, notifying operators and maintenance technicians centrally at their workstations if there is a problem with the device or it needs service. There is also a database containing a copy of all the device configurations and an audit trail of configuration changes made and calibration performed. IDM software is usually considered part of the system, but has an instrument database separate from DCS database although shared database information is kept in synch with the DCS as changes are made. The architecutr typically includes one database server and multiple client workstations, although in a small plant a single computer can be used.

IDM software requires communication infrastructure for continuous monitoring of device health to be in place. It cannot be done effectively with ad-hoc connection of a handheld field communicator or laptop in the field.

[1] See separate white papers on calibration, diagnostics, and device setup/calibration.

Note that handheld field communicator is still very useful for work in the field, on devices that have indeed failed. Make sure the plant has units available.

5.5.1 Selecting IDM Software

IDM software must support the chosen protocols, such as 4-20 mA/HART, FOUNDATION fieldbus, PROFIBUS-DP, and WirelessHART

The device integration technology for asset management systems and configuration software shall be EDDL (IEC 61804-3) with graphical enhancements. For FOUNDATION fieldbus, the system must support "device level access" (DD v 5.1). Wizards (methods) and conditionals must also be supported.

IDM software requires some features over and above device configuration software.

The IDM software should support audit trail for device configuration changes made to enable backwards traceability, for all device types, not just some.

OPC server for online data access from third-party software to live diagnostics and internal variables must be provided, and shall be supported for any device, not just some.

IDM software client must be installed in the DCS operator consoles. Operator access shall be limited to device diagnostics and monitoring of internal variables only. No access to device configuration shall be provided to operators.

5.5.2 Location of IDM software

Even the location of workstations with IDM software clients is something which has to be taken into account when planning control rooms, in order to make device diagnostics a natural part of the daily work process. In the past, IDM software fell into disuse because it was not easily accessible

5.5.3 IDM Software Upgrade

Existing IDM software using the old DD technology or some other device integration technology must be upgraded to software using EDDL with enhancements, for maintenance technicians to enjoy the ease of use provided by a graphical user interface, while at the same time the system administrators enjoy the ease of device revision management provided by text-based files.

Upgrade IDM software from DD to EDDL, and migrate non-DD/EDDL to EDDL. The HART, FOUNDATION fieldbus, and PROFIBUS devices remain the same, since there is no DD, EDDL, or FDT/DTM in the devices.

For systems that do not yet have IDM software, make sure to get it.

5.6 DCS and RTU

Depending on the application, process control may be done using a DCS, PLC, or RTU. RTUs are used in remote applications such as well heads and reservoirs etc. These may all be used with devices having 4-20 mA/HART, FOUNDATION fieldbus, PROFIBUS, and WirelessHART signals.

For 4-20 mA/AI/AO cards, the DCS or RTU should have HART communication embedded, enabling the communication to pass the diagnostics in the device through to IDM software. An old DCS or RTU without digital communication in the AI and AO cards, or using legacy proprietary protocols, requires a HART multiplexer (MUX) to be installed and connected to in parallel with the AI and AO cards to enable IDM software to access the diagnostics in the 4-20 mA/HART devices.

Embedded HART communication in AI and AO cards is preferred over use of separate HART multiplexer as it makes the system simpler and more reliable.

For FOUNDATION fieldbus and PROFIBUS interface cards, make sure the protocols are supported by native system interface cards and configuration software, as intermediate gateways and third-party software may make the system more difficult to administer.

The operational philosophy of the plant may have to change in order to make full use of the device's self-diagnostics. Device diagnostics must be institutionalized in daily work processes. Early warning to operators of impending process problems resulting from device failure requires the DCS operator console to be able to annunciate device diagnostic alarms for failure (not for maintenance etc.) of critical (not non-critical) devices that have an impact on the process, and be able to display the diagnostics page for the device as designed by the device manufacturer.

EDDL makes it possible to display device diagnostics in the DCS operator console, the way the device manufacturer intended to be displayed, in three clicks or less

5.6.1 Selecting DCS and RTU

The DCS or RTU must support the chosen protocols. Do not select proprietary interfaces for new systems.

For 4-20 mA/HART devices, select HART communication built into the 4-20 mA I/O cards of the DCS or RTU. Do not select separate HART multiplexers for new systems.

The DCS and RTU must pass device setup and diagnostics data from all the intelligent 4-20 mA/HART, FOUNDATION fieldbus, PROFIBUS, and WirelessHART devices to the IDM software.

A DCS must support prioritization and classification of device diagnostic alarms in field devices depending on the criticality of the device and the severity of the problem, to enable filtering of where device alarms go, and sorting according to urgency.

An IDM software shall be loaded on the DCS operator consoles such that when a device diagnostics alarm occurs on the DCS operator console, it shall be possible to open the device in IDM software client on the same workstation in three clicks or less. Only device diagnostics and monitoring of internal variables shall be possible from the DCS operator console. Device configuration shall not be possible from the operator console.

5.6.2 DCS and RTU Upgrade and Migration

If the 4-20 mA I/O in the DCS or RTU uses proprietary smart communication, or does not suppport communication at all, then upgrade the I/O cards to 4-20 mA/HART. If that is not possible, then a HART multiplexer must be installed in parallel with the I/O to access the setup and diagnostics information in the 4-20 mA/HART devices. Alternatively, 4-20 mA/HART devices can be fitted with wireless adapters, such that setup and diagnostics information can be accessed through a wireless gateway.

HART Multiplexers

A separate hardwired multiplexer is acceptable for upgrade of existing systems, but should not be used for new installation. When purchasing a new DCS or RTU, and if 4-20 mA cards will be used, make sure the AI and AO cards have HART communication built-in.

5.6.3 Integrated Diagnostics Display

IDM software based on EDDL can be tightly integrated with the DCS such that device diagnostics can be displayed on operator consoles, enabling integrated diagnostics display which in turn enables device diagnostics to become a natural part of maintenance and operations. IDM software instead based on device driver component furnished by the device manufacturers must be run on separate computers since third-party software component are not permitted on the DCS itself.

6 Assign Responsibilities

A number of persons are involved in the initial deployment of the IDM system and sustaining the IDM system and associated work processes for the long-term. The person that is responsible for roll-out of new practices for instrumentation should be on the IDM team, and is best suited as a lead for the IDM team. The plant management is instrumental to lead the cultural change required to institutionalize IDM in daily plant activities. This includes providing required resources for the deployment of the IDM system, and the continued running of the IDM system for the long-haul. The turnaround manager or project manager needs to be on the IDM project team to manage the work and resources required to deploy the IDM system. Identify the persons responsible for work processes associated with the control system and RCM. Establish a cross-functional IDM team of instrumentation, control system, and maintenance specialists to also be experts on IDM to support the IDM system for the long-term. Identify the person for the long-term role of analyzing the reports from the IDM system to schedule maintenance. Develop an organization chart for the IDM team.

7 Plan Deployment

The IDM team leader should develop and document a plant-specific plan for how the IDM system will be deployed at the specific site. This should include a schedule for when each phase of the project will take place and resources required; plant audit, FEED, when people will take on their new roles, detail design, implementation, testing, commissioning, rewriting of procedures, as well as detail plans for training of people in different roles.

8 Detail Design

Turning all device diagnostic alarms off would result in reactive maintenance. Sending all device diagnostic alarms to everyone would result in alarm flooding. A formal detail design process should be adopted to rationalize device diagnostic alarms, similar to process alarms. Engineering the device alarm management, is about making sure the criteria for good device diagnostic alarms are met. This includes prioritizing assets and classifying alarms. This is a new engineering service required regardless of the protocol used being HART, FOUNDATION fieldbus, or PROFIBUS. Make sure to specify it for tender bid documents. Be prepared to pay for engineering hours. Typically the IDM system supplier provides these engineering services.

8.1 Good Device Alarms

The EEMUA 191 alarm management specification defines eight criteria for a "Good Alarm". The criteria can be adapted to a “Good Device Diagnostic Alarm”.

Relevant	Sent to the right person: technician, as well as operator if it has an impact on the process
Unique	Not merely a repetition of information from another diagnostic alarm
Timely	At the right time, comes up neither long before intervention is necessary nor too late for action to be taken
Prioritized	Criticality of the device to the process, indicates the urgency of the problem requiring action
Understandable	Contains a clear message that is easily understood, not a cryptic code

Diagnostic	Helps with the identification of the problem
Advisory	Provides guidance towards the correct action
Focusing	Directs attention to the important aspects

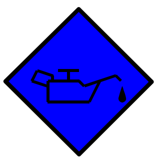
8.2 Categorize Device Type Diagnostics

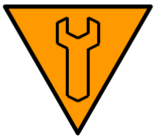
Each device type has self-diagnostics that detect many kinds of problems. Not every device problem detected is equally serious. The diagnostics detected and reported by each device type shall be categorized, or optionally suppressed altogether, such that it can be filtered and routed to the relevant person; operator or maintenance. Device diagnostics alarms that require process intervention should go to both operators and maintenance. Only about 10% of device diagnostics alarms need to be routed to operators to take action. Device diagnostic alarms that do not require action to be taken on the process shall only go to maintenance. Most device diagnostics alarms require no operator action. By categorizing the device diagnostic alarms, the IDM software can handle these alarms correctly, routing them to the relevant person. An important part of device alarm rationalization is to map each device diagnostic alarm to a desired category. The desired mapping shall be documented.

8.2.1 NAMUR NE107 Status Signals

The NAMUR NE107 recommendation uses four "status signal" categories to which device diagnostics alarms can be mapped. Three of these status signals indicate severity of the problem in the device: *'Failed'* (a very severe device problem), *'Off Specification'* (intermediate severity), *'Maintenance Required'* (low severity), and *'Check Function'*. The last status signal, 'Check Function', does not indicate severity and is not quite a diagnostics alarm, but rather an indication some technician is working on the device. The status signals are summarized in table 6 together with icons and color coding. The device manufacturer can recommend and pre-configure the categorization for each diagnostics alarm for the device type, but it is possible for each plant to redefine this setting. The categorization should be defined or reviewed by the plant's instrumentation specialist. The chosen categorization will be configured in the system. This process requires a list of device types used in the plant, and lists of the diagnostics available in each of these device types.

Table 6 NAMUR NE107 "status signals"

Category	**Icon**	**Severity**	
Failed		High	Output signal invalid due to malfunction in the field device or its peripherals.
Off Specification		Medium	The device is operating outside its specified range (e.g. measuring or temperature range) or that internal diagnoses indicate deviations from measured or set values due to internal problems in the device or process characteristics (e.g. bubble formation in flow metering).
Maintenance Required		Low	Although the output signal is valid, the wear reserve is nearly exhausted or a function will soon be restricted due to operational conditions e.g. build-up of deposits.

Check Function		N/A	Output signal temporarily invalid (e.g. frozen) due to on-going work on the device.

Device alarms will be displayed in the IDM software and DCS with icons and color coding. Good device health is indicated by the absence of an icon, or in some system displays using a green icon.

8.3 Prioritize Device Tags

Define the criticality of the device to the process, to indicate the urgency of the problem requiring action based on impact on plant safety, regulatory compliance, product quality, process throughput, maintenance cost, operational cost. Once the IDM system is operational, this will drive how maintenance prioritizes their work. The prioritization should be defined or reviewed by operations and process engineers. This process can leverage work already done as part of RCM and other assessments. The chosen priority will be configured in the system. This process requires a list of all device tags in the plant. The desired priorities shall be documented.

Note that likelihood of device failure is not taken into account because when a failure alarm is received, the likely hood of a failure is 100% since it has actually happened.

9 Implementation

At the implementation stage the IDM software device database \is built, device templates created, devices configured, and reports defined based on the detail design. This involves the IDM supplier, plant instrument specialist, and plant system engineer.

9.1 System Device Database

The IDM software database has to be built including a complete instrument list. This is usually accomplished by the IDM software auto-discovering the network hierarchy and all the underlying devices. This eliminates manual creation and ensures there is no mismatch between the IDM database, the DCS database, and the actual installation. For the IDM software to auto-discover the network hierarchy and devices, it must be connected to all the devices which only happen after commissioning at site. However, using I/O simulation module during FAT provides an opportunity for the network hierarchy and devices to be auto-discovered much earlier.

In addition to the auto-discovering the network hierarchy, a plant location hierarchy shall also be created to make it possible for technicians and operators to navigate devices not by only by their location in the network hierarchy, but also by their location in the plant; Area, Unit, Equipment Module, and Control Module based on the ISA88 hierarchy. This plant location hierarchy has to be created manually, and the devices dragged and dropped (from the network hierarchy) into their respective Control Module.

9.2 Device Configuration

The device alarm categorization and priority developed in the detail design phase shall be configured into the devices along with other settings required to make the device diagnostics work.

9.2.1 Device Diagnostic Alarm Category and Priority

The device alarm categorization and priority controls how the device diagnostic alarm is routed in the system; to both maintenance and operators, or just maintenance.

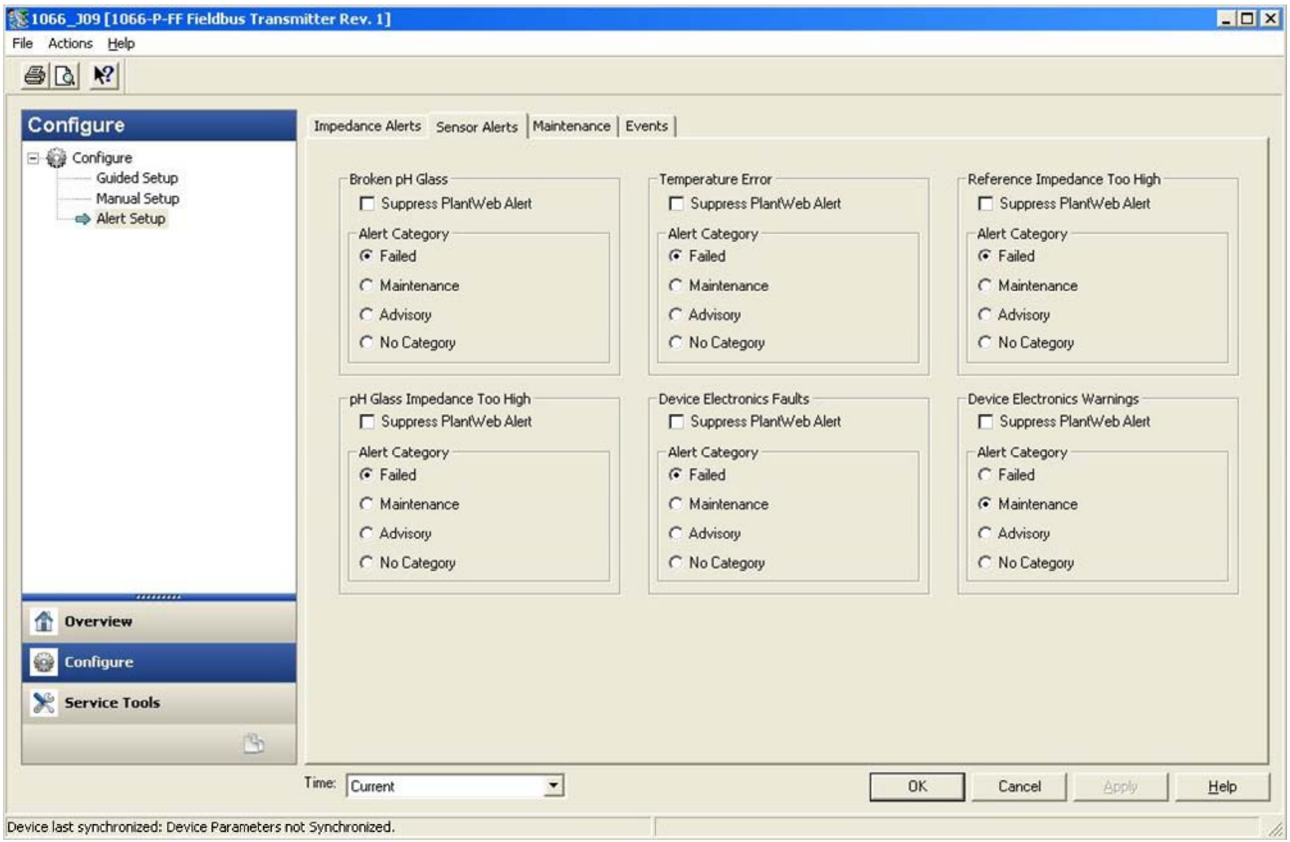


Figure 2 Device diagnostics alarm category configuration and suppression in a device presented using a user interface rendered using EDDL

9.2.2 Device Diagnostic Alarm Detection Settings

Many devices have diagnostics that works without configuration. However, other device diagnostics need to be adjusted for the specific application. For instance, a valve positioner needs a limit to be set for the minimum acceptable supply pressure for the actuator.

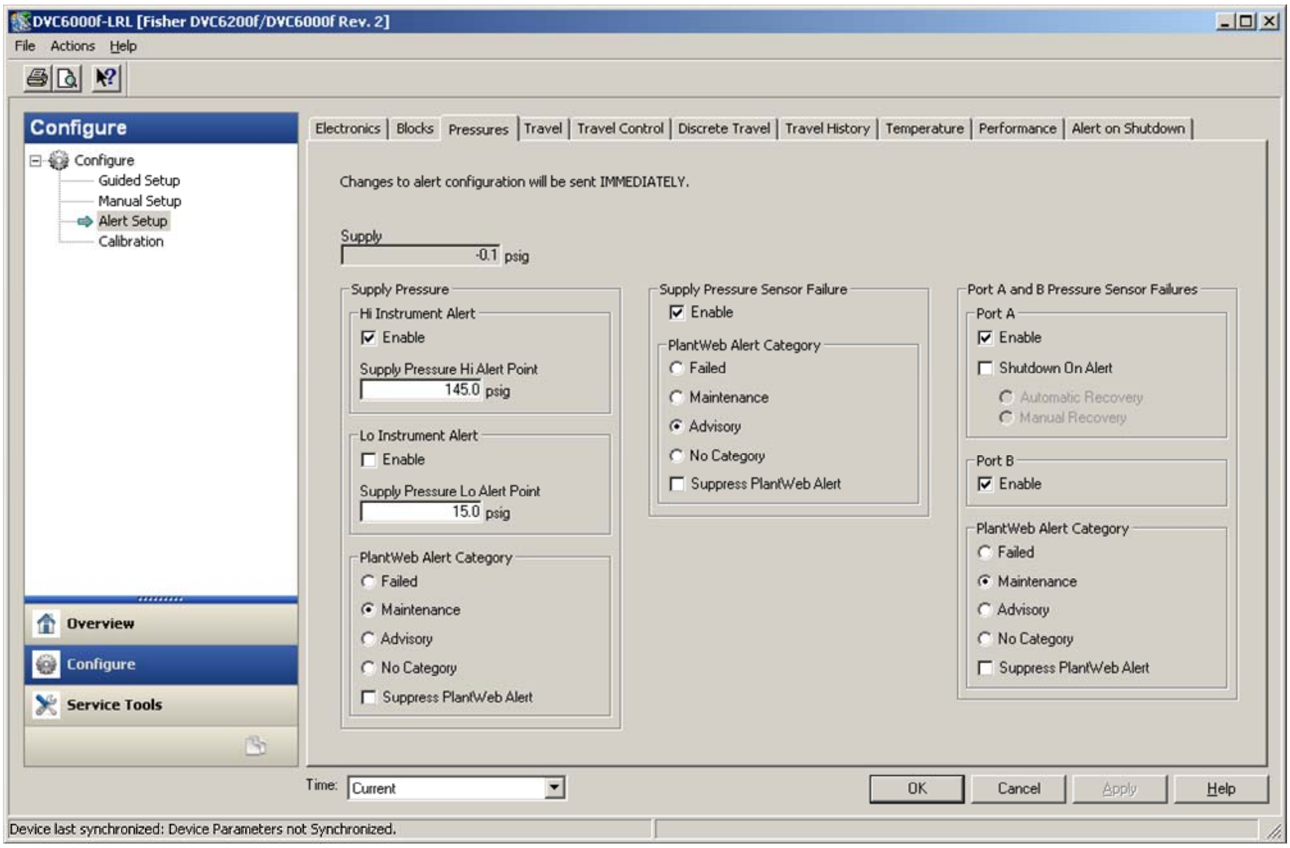


Figure 3 diagnostics configuration in a device presented using a user interface rendered using EDDL

9.3 System Device Alarm Categorization

For 4-20 mA/HART devices and many FOUNDATION fieldbus devices the categorization of device alarms is not done in the device, and therefore not configured in the device. That is, NAMUR NE107 or equivalent device diagnostics alarm categorization is not supported in the device itself. However, the DCS or IDM software alarm management can instead provide centralized NAMUR NE107 or equivalent device diagnostics alarm categorization.

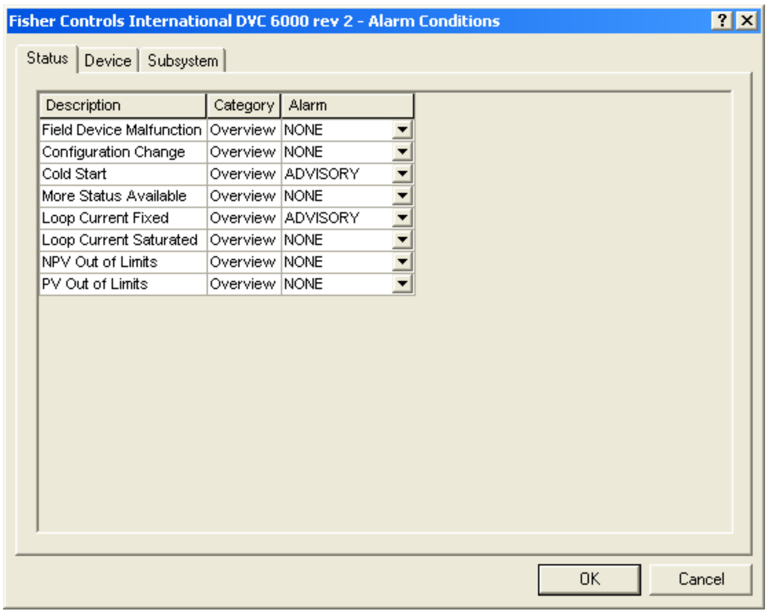
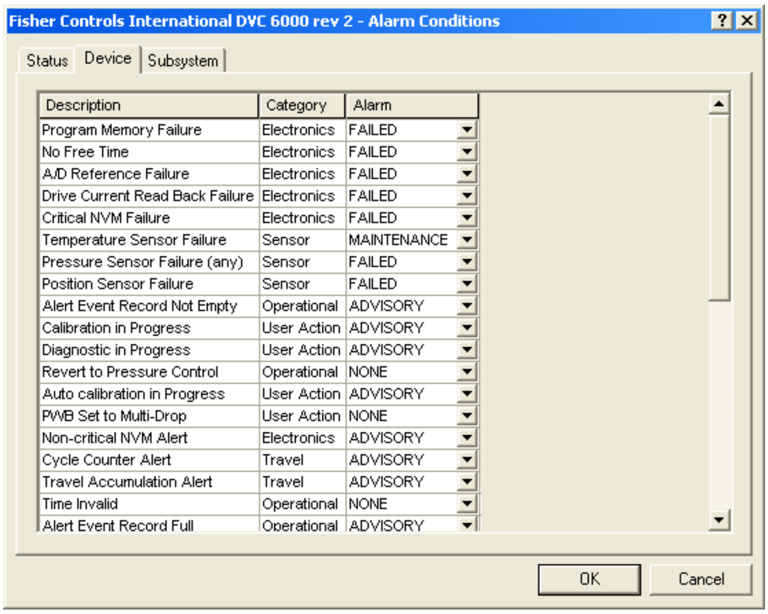


Figure 4 Universal HART response code categorization



Description	Category	Alarm
Program Memory Failure	Electronics	FAILED
No Free Time	Electronics	FAILED
A/D Reference Failure	Electronics	FAILED
Drive Current Read Back Failure	Electronics	FAILED
Critical NVM Failure	Electronics	FAILED
Temperature Sensor Failure	Sensor	MAINTENANCE
Pressure Sensor Failure (any)	Sensor	FAILED
Position Sensor Failure	Sensor	FAILED
Alert Event Record Not Empty	Operational	ADVISORY
Calibration in Progress	User Action	ADVISORY
Diagnostic in Progress	User Action	ADVISORY
Revert to Pressure Control	Operational	NONE
Auto calibration in Progress	User Action	ADVISORY
PWB Set to Multi-Drop	User Action	NONE
Non-critical NVM Alert	Electronics	ADVISORY
Cycle Counter Alert	Travel	ADVISORY
Travel Accumulation Alert	Travel	ADVISORY
Time Invalid	Operational	NONE
Alert Event Record Full	Operational	ADVISORY

Figure 5 HART device specific device diagnostics alarm categorization

10 Integration and FAT

For a new plant the IDM and DCS are tested in an integrated FAT at the staging facility before shipping to site. For an existing plant that already has a DCS, the IDM will be staged and tested alone. At FAT, test that only device diagnostics alarms with the prescribed category and priority are routed to the operators, and that all other device diagnostics alarms go only to maintenance. Verify that the report formats are correct. Make sure all versions of all device types from all manufacturers using all protocols are integrated, by opening the device display for each one. This involves the IDM supplier, plant instrument specialist, and plant system engineer.

11 Commissioning

For a new plant the IDM, DCS, and field devices are commissioned together. For an existing plant that already has a DCS and field devices, the IDM will essentially be commissioned alone, although some device types have diagnostics that need to be commissioned tag by tag.

11.1 IDM Software Commissioning

Once at site, make the IDM software auto-discover the network hierarchy and underlying devices to ensure the IDM database is up to date and in sync with the DCS database and the actual installation. Upload the factory settings from all devices to the IDM database.

11.2 Device Diagnostics Commissioning

Some device types have diagnostics that need to be commissioned one device tag at the time. This particularly applies to the process problem diagnostics such as detection of process noise and plugged impulse lines which requires the device to 'learn' a baseline of what the normal process operation is like so as to distinguish it from abnormal conditions. This could be done after the plant startup, and need not be part of the busy commissioning phase

If the initial valve signature file for the control valves have not been provided by the valve manufacturer, capture signature once the busy period of the commissioning is over

12 Rewriting Procedures

Rewrite the maintenance procedures and work processes that technicians follow to include use of the IDM software and device diagnostics to screen and prioritize maintenance issues. This will make use of IDM software routine in maintenance tasks. Rewriting of procedures can start early in the project and does not need to wait for detail design to be completed. This involves the plant instrument specialist and the maintenance lead.

12.1 Ad-Hoc Maintenance Call Out Case

Maintenance occasionally gets calls from operations to check on devices, often in response to an alarm. The maintenance procedure for handling such cases shall be rewritten such as to check the IDM software first centrally from the desktop, before going to the field, to first of all confirm if there indeed is a problem with the device or if the case can be closed. If the device indeed has a problem, review the device diagnostics and the device manufacturer recommended actions to determine which tools, spares, and documentation should be brought along to the field. From this point on, existing procedures for obtaining work permit, management of change, maintenance log, and closeout etc. apply.

12.2 Daily Maintenance

At the morning meeting at the beginning of the shift the maintenance lead and technicians plant the work for the day. The daily maintenance procedure shall be rewritten such as to check the IDM software first, before the meeting, to generate the report of device alarms from the IDM software. From this point on, existing procedures for assigning technicians to carry out the work etc. apply. Throughout the day maintenance technicians work their way through the list of devices requiring attention, starting with the highest priority devices (based on severity and criticality) in the IDM software. From this point on, existing procedures for obtaining work permit, management of change, maintenance log, and closeout etc. apply.

12.3 Periodic Turnaround

Turnarounds are required from time to time. Turnarounds have to be planned well in advance. The procedures for turnarounds and the pre-planning shall be rewritten such as to screen the devices from the IDM software before the turnaround shutdown, while the plant is still running. The health of valves, flowmeters, and other devices become inputs for the turnaround planning process.

12.4 Operator Device Diagnostic Alarm

Few, less than 10%, of device diagnostic alarms are routed to the operators at the DCS operator workstation. These device diagnostic alarms are usually outright device failures. The operator procedure in case of a device diagnostic alarm shall be to first tend to the process, taking whatever action required. By providing detailed diagnostics in device faceplates and the device manufacturer diagnostics displays in the operator workstation, the operator will have a better understanding of how the device failure might affect the process, and how soon. Once the operator has settled the process, the operator shall notify maintenance of the device failure.

Note, the operator does not repair device. The operator tends to the process, because within minutes or hours of a device failure, the process will inevitably be affected. The device diagnostic alarm becomes an early warning to the operator.

13 Training for Competency

In the past the operators received training on the operator station software, but not the IDM software. The instrument technicians got trained on the handheld field communicator, but not the IDM software Use of IDM requires new skills. Therefore training is required for all those involved to get the necessary competency in IDM. With IDM, work is centered around computers. Therefore, computer skills are a prerequisite for maintenance work in a modern plant. IDM training has to be customized to cover the competencies required for the tasks which each role has to carry out. Training has to be carried out not at the end of the project, but throughout the duration of the project before the next phase of the project starts. Once the plant is operational, new employee training and refresher courses should be conducted periodically.

Role	Tasks	Competencies
• Plant management • Project/turnaround manager	• Justification • Planning	• Understand IDM and predictive maintenance regimes
• Instrument lead • Control system lead	• Audit • FEED	• Understand IDM requirements • Understand IDM system architecture
• Instrument specialist • Process engineers	• Detail design	• Understand network protocols • Understand device diagnostics • Understand device integration • Understand the device alarm categorization and prioritization
• System engineers	• Implementation • Integration • FAT	• How to configure device diagnostics • Understand device templates • How to configure system alarm management • How to configure system reports
• Maintenance technicians	• Commissioning • Maintenance	• Understand the device alarm categories and priority • Navigate the device menu: overview, service tools • How to configure and tune device diagnostics • How to extract and print daily reports • Search for tags • Search for specific classes of instruments (pH, gas chromatograph etc.) in a particular plant unit
• Maintenance manager	• Rewrite procedures	• How to write maintenance procedures based on IDM software

The IDM software supplier should be able to assist with training material and conducting these classes. Training cost should be included as part of the project budget. Training shall not be generic, but must be task-based and site-specific, using the same IDM software as the site. Handouts and manuals must be provided.