Troubleshooting Instrumentation & Control Systems

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Reasons for Troubleshooting

- Something not functioning properly
- You don't know what's wrong
- Equipment down or product out of specifications
- Isolate problems between the equipment and the process
Purpose of Troubleshooting

• Maintain Safety of Personnel and Plant Equipment

• Identify the problem

• Minimize down time

• Improve plant efficiency

• Improve product quality
Bottom Line Goals

• No unscheduled downtime

• Product running at specifications

• All instruments, controls, etc. are operating properly

• Reduce maintenance cost

• Minimize troubleshooting time

• Improve employee efficiency
Bottom Line Goals - Impact Statement

- The global process industry loses $20 billion, or five percent of annual production, due to unscheduled downtime and poor quality.*

- ARC estimates that almost 80 percent of these losses are preventable and 40 percent are primarily the result of the operator or human in the loop. *

- ARC estimates unplanned downtime accounts for the equivalent of 20% of all production in the process industries. A single unplanned shutdown can wipe out your plant profit for the year. **

* 2009 Fieldbus Foundation - FFIEUC-Mumbai Conference
** NAMUR NE 107 recommendations come to the United States – Larry O’Brian
Wasted Effort

63% of maintenance labor results in no action.

Routine check: 35%
No problem: 28%
Calibration shift: 20%
Zero off: 6%
Plugged lines: 6%
Failed: 4%

Wasted Effort
Figure 1. End users estimate that more than half of maintenance activities result in no action. Predictive diagnostics can help users develop a proactive maintenance strategy that avoids unnecessary trips to the field for routine scheduled maintenance.
What Are You Expected to Troubleshoot?

- Process
- Loop
- Device
- Discrete components
- Pneumatic equipment
- Electronic equipment
- Digital systems
- Networks
- Analytical systems
- Computers
- Board or module
- Process equipment
- Operation procedures
Skills Beneficial for Troubleshooting

• Certain skills can be helpful in troubleshooting
  – Logical or methodical approach
  – Ability to learn from past experiences
  – Curiosity
  – Patience
  – Self-motivated
  – Knowledge of information location
  – Use of computer based information
    – Drawings
    – Spare parts
Troubleshooting Skills Dependent On

- Your level of expertise
- Familiarity with your instrumentation or equipment
- What test equipment you have & familiarity with it
- Your company’s philosophy
- Access to information resources
- What parts you have available (for repair)
- What time frame you have
Steps to Logical Analysis Troubleshooting

• Whatever troubleshooting method is used, a logical approach should be taken to identify and repair a problem
  – Verify that something is wrong
  – Identify and locate the problem
  – Fix the problem
  – Verify the problem is fixed
  – Follow-up to prevent future problems
Verify That Something is Wrong

- Ask the operator
- Observe for yourself
- Is the process being operated under normal conditions and productions rates
- Begin with and test with the assumption that the instrumentation and controls are not the problem
- Familiarize yourself with the loop
- Make sure you understand how the controls are supposed to function when operating properly
- Make sure you understand the associated equipment and how it can influence the operation of the suspect equipment
Identify and Locate the Problem

• Confirm whether the instrumentation and control or something else is causing the problem
  – Make the easiest checks first
  – Can the desired control be achieved with the control loop in manual?
  – Could the measuring instrument be correct and actually showing that something has changed in the process?
  – Isolate the problem to the instrumentation and controls or to something else (process, equipment, etc.)
  – Inform Production of the steps that you are taking that could cause an upset, alarm, etc.
  – Work to isolate the source of the problem using one of 3 methods
    – History
    – Input/Output
      – Series
      – Divide and Conquer
• Develop a plan for how to proceed to locate and confirm cause
Fix the Problem

• Once you feel the problem has been isolated, develop a plan to repair the problem

• Inform Production of your repair plan

• Repair or recommend the repair of the problem

• Follow production area safety procedures and manufacturer specifications and procedures during repair

• Communicate closely with Production
Verify that the Problem Is Fixed

- Confirm that all repaired and associated parts of the system operate correctly, including
  - Measurements
  - Control
  - Alarms
  - Interlocks

- Confirm that the Operator is satisfied with the performance of the repaired system and understands how it is to operate under all conditions
Follow Up to Minimize Future Problems

- Document in history file
- Suggest changes, if needed
- Upgrade PM program
- Submit changes to update all documentation (As built)
Documentation for Troubleshooting

- Current documentation is as important a troubleshooting tool as any test equipment or other tools
  - Process & Instrument Diagrams – P&ID
  - Instrument loop diagram
  - Instrument maintenance records
  - Instrument specifications and manuals
  - Electrical – motor control schematics
  - Interlock and alarm information
  - System drawing
  - Operational logs/procedures and data
Troubleshooting Framework Review

Verify something is wrong

Identify and locate the problem

Repair the problem

Verify the repair

Follow-up

Question, confirm

Method?

1. Equipment procedures
2. Develop a plan
3. Select method

- Equipment History
- Input/Output – Serial
- Input/Output – Divide and Conquer
- Shot Gun

Other methods
- Substitution
- Fault insertion
- Remove and conquer
- Circle the wagons
- Trapping
- Complex-to-simple
- Consultation
- Intuition
- Out-of-the-box
- Vendor assistance

Develop a plan to repair

Document, or changes

Confirm
Pneumatic Test Equipment

Dead Weight Tester

Calibration Gauge

Pressure Gauge

Dead Weight Tester

Calibration Kit

Pressure Module

Electronic

Calibration Pump

Pressure Calibrator/Recorder
Electronic Test Equipment

- DVM (True RMS)
- Process Calibrator
- mA Clamp Meter
- HART Hand Held
- Process Calibrator (Low Cost)
- Pressure Calibrator
- IR Temp
- Torque Screwdriver
- HART USB Modem
- HART – Smartphone + blue tooth
- Dry Blocks
Digital Test Equipment

- RJ-45 Tester/Wire Mapper
- Fieldbus Monitor
- Profibus PA Monitor
- Wiring Validator
- LAN Trouble Shooter
- Wireless Kit
- ProfiTrace Analyzer
- Wire Mapper – Cable Tester
- Digital/Storage Scopes
Old Smart Phones

WhatsApp
Skype
You Tube

Bar Code Scanner
Bubble Level
Strobe Light
Sound Meter
Red Laser
Camera
Flash Light

Quick Office
EsFile Explorer
Wifi File Explorer
Notes
Cam-Scanner
Convert Pad
Math Calculators
Ohms Law Calculator
Instrument Range Calculator
RTD/TC Calculators

E&H Instrument Lookup
HART Calibrators
Loop Tuners

Google Drive
Box.com
Pictures
Instruction Books
Notes
Books

PdaNet
Process Control

• The *regulation or manipulation of variables* influencing the conduct of a process in such a way as to obtain a product of desired quality and quantity in an efficient manner.
Instruments in a Feedback Control Loop

Upsets or Disturbances → Process

Manipulated Variable → Process

Controlled Variable → Sensor

Setpoint → Controller

Controller → Signal Transducer

Signal Transducer → Final Control Element

Final Control Element → Setpoint

Transmitter

Recorder

Indicator

Alarms

Interlocks
Current Loop Characteristics

Standard Signal Values (250 ohm)
- 4mA = 1 vDC = 0%
- 8mA = 2 vDC = 25%
- 12mA = 3 vDC = 50%
- 16mA = 4 vDC = 75%
- 20 mA = 5 vDC = 100%

[Diagram showing current flow and load resistance]
## Other Current Loop Characteristics

### Comparison of Voltages at Load and Transmitter (PS = 24vDC)

<table>
<thead>
<tr>
<th>%</th>
<th>mA</th>
<th>$R_{\text{load}} = 250 , \Omega$</th>
<th>$R_{\text{load}} = 100 , \Omega$</th>
<th>$R_{\text{load}} = 62 , \Omega$</th>
<th>$R_{\text{load}} = 5 , \Omega$</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>20.0</td>
<td>5v</td>
<td>2v</td>
<td>1.24v</td>
<td>0.1v</td>
</tr>
<tr>
<td>75</td>
<td>16.0</td>
<td>4v</td>
<td>1.6v</td>
<td>0.992v</td>
<td>0.08v</td>
</tr>
<tr>
<td>50</td>
<td>12.0</td>
<td>3v</td>
<td>1.2v</td>
<td>0.744v</td>
<td>0.06v</td>
</tr>
<tr>
<td>25</td>
<td>8.0</td>
<td>2v</td>
<td>0.8v</td>
<td>0.496v</td>
<td>0.04v</td>
</tr>
<tr>
<td>0</td>
<td>4.0</td>
<td>1v</td>
<td>0.4v</td>
<td>0.248v</td>
<td>0.02v</td>
</tr>
</tbody>
</table>

### NAMUR Standard NE-43

- >22.0 mA: Wiring Problem (short)
- 20.5 – 22.0 mA: Transmitter Failure
- 20.0 – 20.5 mA: Normal Over Range
- 4.0 – 20.0 mA: Normal Operation
- 3.8 – 4.0 mA: Normal Under Range
- 3.6 – 3.8 mA: Transmitter Failure
- 0 – 3.6 mA: Wiring Problem (open)
Instrument Symbols & Identification

- Functional identification
- Instrument numbering
- Functional locations
- Signal transmission
- Measuring element symbols
- Final control element symbols
- Example P&ID
Example – Balloons and Tags

Flow Transmitter
In Field

Flow Controller
In BPCS

Flow Valve
In Field
Instrument to Instrument Connection Symbols

- INSTRUMENT SUPPLY OR CONNECTION TO PROCESS
- UNDEFINED SIGNAL
- PNEUMATIC SIGNAL
- ELECTRONIC SIGNAL
- HYDRAULIC SIGNAL
- CAPILLARY TUBE
- ELECTROMAGNETIC SIGNAL (GUIDED)
- ELECTROMAGNETIC (WIRELESS) SIGNAL (UNGUIDED)
- COMMUNICATIONS LINK – BETWEEN SYSTEM DEVICES
- COMMUNICATIONS LINK – TO/FROM SMART (HART) DEVICE
- COMMUNICATIONS LINK – TO/FROM INTELLIGENT (FIELDBUS) DEVICE
- COMMUNICATIONS LINK – BETWEEN TWO SYSTEMS (e.g. DCS and SIS)

Refer to ISA5.1 Table 5.3.2 for additional symbols
Flow Measuring Element Symbols

- Orifice plate or restriction orifice
- Pitot tube
- Turbine flowmeter
- Vortex shedding flowmeter
- Magnetic flowmeter
- Thermal mass flowmeter
- Positive displacement flowmeter
- Cone flowmeter
- Coriolis mass flowmeter
- Sonic flowmeter
- Open channel flume

Refer to ISA5.1 Table 5.2.3 for additional symbols
Piping & Instrumentation Drawing (P&ID)

COLD FLUID IN

CONDENSATE RETURN

STEAM
## Example Loop Diagram

### Field Process Area

**Transmitter:**
- **Model:** 823-DP
- **Spec No:** CS-E/F-D-A

*Orifice I.D. - 1.281"*

*Ratio = .62*

**Valve:**
- **Model:** 48-21135
- **Spec No:** CS-E/F11-A

**Notes:**
1. FV-301 fully open at 3 PSIG and fully closed at 15 PSIG
2. All cables are 18g. Shielded

### Field Junction

**Transducer:**
- **Model:** E27AM-SA
- **Case/Pos:** 1/3
- **Spec No:** 6018743

### Panel Rear

**Transducer:**
- **Model:** E27AM-SA
- **Case/Pos:** 1/3
- **Spec No:** 6018743

### Panel Front

**Reference Drawings:**
- **P&ID 2150-70**
- **Instrument Installation Details 423-1**
- **Control Board Specification 100-33**

**MIXING SYSTEM #1**

**INDUSTRIAL PROCESS CORP**

**Drawn By**

**Checked By**

**Approved By**
Portable Training Lab
Portable Training Lab – Instrument Air Diagram
Troubleshooting Safety

- Electrical hazards
- Compressed air hazards
- Test equipment
- Working with energized ("live") equipment
HART Systems Review

- Highway addressable remote transducer
- A “hybrid” analog/digital technology
- An instrument’s primary variable is transmitted via 4-20mA
- A de facto standard for field communication
- Communication is modulated as an AC signal superimposed onto the 4-20mA signal
- Uses frequency shift keying (FSK)
- Utilizes a device description (DD) language
- Enables asset management
## HART COMMANDS: OVERVIEW

<table>
<thead>
<tr>
<th>Universal</th>
<th>Common Practice</th>
<th>Device Specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read device type</td>
<td>Read dynamic variables</td>
<td>Read /write low-flow cut-off</td>
</tr>
<tr>
<td>Read PV and units</td>
<td>Write damping time constant</td>
<td>Start, stop or clear totalizer</td>
</tr>
<tr>
<td>Read current output and percent of range</td>
<td>Write device range value</td>
<td>R/W density calibration factor</td>
</tr>
<tr>
<td>Read predefined dynamic variables</td>
<td>Calibrate (set zero, set span)</td>
<td>Choose PV (mass, flow, or density)</td>
</tr>
<tr>
<td>R/W tag, descriptor, date</td>
<td>Set fixed output current</td>
<td>R/W materials or construction information</td>
</tr>
<tr>
<td>R/W 32 character message</td>
<td>Perform self-test</td>
<td>Trim sensor calibration</td>
</tr>
<tr>
<td>Read range values, units, and damping time constant</td>
<td>Perform master reset</td>
<td>PID enable</td>
</tr>
<tr>
<td>R/W final assembly number</td>
<td>Trim PV, zero</td>
<td>Write PID set point</td>
</tr>
<tr>
<td>Write polling address</td>
<td>Write PV unit</td>
<td>Valve characterization</td>
</tr>
<tr>
<td></td>
<td>Trim DAC zero and gain</td>
<td>Valve set point</td>
</tr>
<tr>
<td></td>
<td>Write transfer function (square root/linear)</td>
<td>Travel limits</td>
</tr>
<tr>
<td></td>
<td>Write sensor serial number</td>
<td>User units</td>
</tr>
<tr>
<td></td>
<td>R/W dynamic variable assignments</td>
<td>Local display information</td>
</tr>
</tbody>
</table>

(Note: this is a partial list of HART commands)
DCS – Troubleshooting Features

- Process graphic display
- Loop display and Detailed Loop Displays
- Real time trends and Historical Data Collection
- Alarms and alarm summary
- Event logger
- Operator action journal
- Sequence of events
- System management
- Sequence Of Events
- Function block details
- Control strategy configuration
- Intelligent field device configuration
- Change management
NAMUR – NE 107

- Requirements regarding self-monitoring and diagnosis in field instrumentation and classification of diagnostic events
- Provides improved operator, engineering and asset management

<table>
<thead>
<tr>
<th>Device Status</th>
<th>Condition</th>
<th>Output Status</th>
<th>HMI Color Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device OK</td>
<td>Normal</td>
<td>Valid output signal</td>
<td>Green</td>
</tr>
<tr>
<td>Comm OK</td>
<td>Normal</td>
<td>Valid output signal</td>
<td>Green</td>
</tr>
<tr>
<td>Maintenance Required</td>
<td>Maintenance Required</td>
<td>Output signal is still valid</td>
<td>Blue</td>
</tr>
<tr>
<td>Warning Maint Required</td>
<td>Maintenance Required</td>
<td>Output signal is still valid</td>
<td>Blue</td>
</tr>
<tr>
<td>Maintenance Mode</td>
<td>Out of Specification</td>
<td>Output signal out of the specified range</td>
<td>Yellow</td>
</tr>
<tr>
<td>Simulation Mode</td>
<td>Function Check</td>
<td>Temporary non-valid output signal</td>
<td>Orange</td>
</tr>
<tr>
<td>Error</td>
<td>Failure</td>
<td>Non-valid output signal</td>
<td>Red</td>
</tr>
<tr>
<td>Config Error</td>
<td>Failure</td>
<td>Non-valid output signal</td>
<td>Red</td>
</tr>
<tr>
<td>Comm Error</td>
<td>Failure</td>
<td>Non-valid output signal</td>
<td>Red</td>
</tr>
<tr>
<td>Process Error</td>
<td>Failure</td>
<td>Non-valid output signal</td>
<td>Red</td>
</tr>
</tbody>
</table>
Tree Maps

Alarms & TreeMapping