

Calibration Verification Practices

Rosemount 8800D Vortex Flowmeters (HART™ Protocol)

INTRODUCTION

This guideline is intended for users of Rosemount 8800D Vortex flowmeters to develop plant specific calibration/verification procedures and is focused on procedures that do not require the removal of the vortex meter body from the line or shutdown of the line. This document shall provide the basis for verification of the calibration of Rosemount 8800D Vortex flowmeters. It does not include calibration applications associated with the FOUNDATION fieldbus communication protocol. It was prepared by Technical Specialists at Rosemount Flow Division's headquarters in Eden Prairie, MN, USA.

Overview

This section is for the use of those who are generally experienced in the calibration and verification of electronic transmitters including the use of a Field Communicator and/or AMS Device Manager. It is not intended to replace the general calibration/verification procedures as detailed in Section 2, the 475 Field Communicator Manual, or the Rosemount 8800 Vortex flowmeter user's manual. This section will outline the documentation and hardware required for calibration/verification of the Rosemount 8800 Vortex flowmeter.

Documentation Required

- Applicable Instrument Specifications (latest revision)
- Instrument Verification Report form (see "Appendix A: Electronics Verification Form" on page 8)
- Factory Calibration Report
- Rosemount 8800D Vortex Flowmeter Manual 00809-0100-4004 (optional)
<http://www.emersonprocess.com/rosemount/document/man/00809-0100-4004.pdf>
- Field Communicator Manual 00809-0100-4276 (optional)
http://www.documentation.emersonprocess.com/groups/public_assetoptprodlit/documents/instruction_manuals/475_allma_usermanual.pdf

If there are any questions, or more information is required, please contact the Rosemount technical support at 1-800-999-9307 or via e-mail at Specialist-Vortex.EPM-RTC@emerson.com.

Hardware and Tools Required:

- Power supply, 10-55 VDC
- Multi-meter, 4-1/2 digits (within NIST traceable calibration compliance time period)
- 475 Field Communicator or AMS Device Manager
- Precision Load Resistor: 250 ohms +/- 0.01% 2 watt or 500 ohms +/- 0.01% 2 watt
- Jumper wires with end connectors
- Temperature Sensor Calibrator or Calibrated Oil Bath (MTA Option Only)

Pre-Configuration Checks (Field Communicator not connected to transmitter)

- Verifying the Security Jumper Status

Insure that power is removed from the transmitter. Remove the housing cover opposite the field terminal side. Position the security jumper as desired. If the Security jumper is not installed – SECURITY OFF (NOT write protected).



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CALIBRATION GUIDELINES

This section provides the calibration verification procedure to follow for a given use case of the Rosemount 8800 Vortex flowmeter.

Calibration/Verification Method Hierarchy

One of the following procedural hierarchies should be followed to verify if an installed vortex meter is functioning properly, and if re-calibration is required. Some procedures may not be required depending on verification results or the application needs. Please see the use cases below and follow the procedures listed for the applicable use case.

Use Case I – 8800D Vortex meter without MTA Option

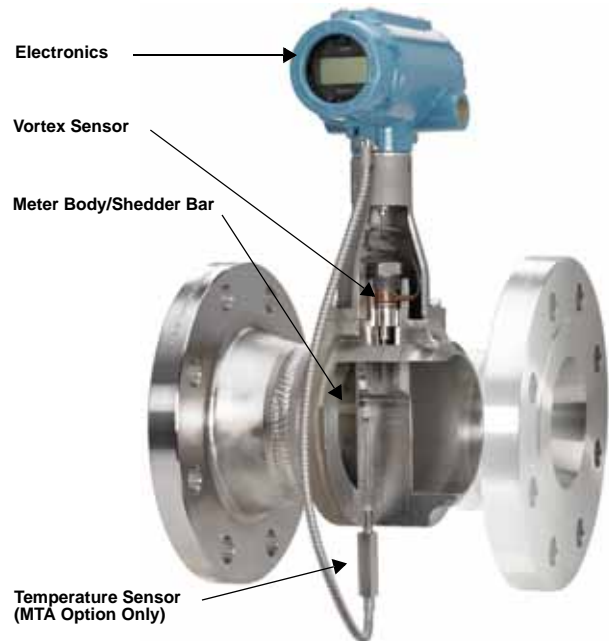
1. Verify Basic Configuration Parameters
2. Electronics Verification through Flow Simulation
3. Vortex Sensor Verification
4. Meter Body/Shedder Bar Verification (*If Required*)
5. Wet Calibration (*If Required*)

Use Case II – 8800D Vortex meter with MTA Option using Process Fluid of T-comp Sat Steam

1. Verify Basic Configuration Parameters
2. Electronics Verification through Flow Simulation
3. Perform Density Test Calculation
4. Vortex Sensor Verification
5. Temperature Sensor Verification
6. Meter Body/Shedder Bar Verification (*If Required*)
7. Wet Calibration (*If Required*)

Use Case III – 8800D Vortex meter with MTA Option using Process Fluids of Gas/Steam or Liquid

1. Verify Basic Configuration Parameters
2. Electronics Verification through Flow Simulation
3. Vortex Sensor Verification
4. Temperature Sensor Verification
5. Meter Body/Shedder Bar Verification (*If Required*)
6. Wet Calibration (*If Required*)



Technical Note

00840-0300-4004, Rev AA

June 2010

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Procedure I: Verify Basic Configuration Parameters

NOTE:

Make sure that the flowmeter is powered properly.

Step 1: Process Fluid

- A. Verify the correct Process Fluid Type has been selected (Gas/Steam, Liquid, or Tcomp Sat Steam).

HART Commands: 1 (Device Setup), 3 (Basic Setup), 2 (Process Config), 2 (Process Fluid)

- A.1 IF the Process Fluid is correct, press HOME to return to the main menu.
A.2 IF the Process Fluid is incorrect, select the correct Process Fluid from the list.

Please note you MUST SEND the data whenever changes are made.

Step 2: Fixed Process Temperature

- B. Verify the correct Process Temperature has been entered.

HART Commands: 1 (Device Setup), 3 (Basic Setup), 2 (Process Config), 3 (Fixed Process Temperature)

- B.1 IF the Process Temperature is correct, press HOME to return to the main menu.
B.2 IF the Process Temperature, enter the correct Process Temperature.

Please note you MUST SEND the data whenever changes are made.

Step 3: Fixed Process Density or Density Ratio

- A. If you are using mass flow units, you must enter the process density. If you are using Standard or Normal volumetric flow units, you must enter a density ratio. The device is also capable of calculating density ratio using the ideal gas law using the process temperature, pressure, compressibility, and the base pressure, temperature, and compressibility.
B. Verify the correct Fixed Process Density has been entered (for mass flow units).

HART Commands: 1 (Device Setup), 3 (Basic Setup), 2 (Process Config), 4 (Density/Density Ratio), 2 (Fixed Process Density)

- B.1 IF the Process Density is correct, press HOME to return to the main menu.

- B.2 IF the Process Density is incorrect, enter the correct Process Density.

Please note you MUST SEND the data whenever changes are made.

- C. Verify the correct Density Ratio has been entered (for standard or normal volumetric flow units).

HART Commands: 1 (Device Setup), 3 (Basic Setup), 2 (Process Config), 4 (Density/Density Ratio), 1 (Density Ratio), 1 (Density Ratio)

- C.1 IF the Density Ratio is correct, press HOME to return to the main menu.

- C.2 IF the Density Ratio is incorrect, enter the correct Density Ratio or choose option 2 to calculate density ratio using the ideal gas law.

Please note you MUST SEND the data whenever changes are made.

Step 4: Reference K-Factor

- A. Verify the correct Reference K-Factor has been selected by ensuring the value entered in the software matches the value on the meter body tag.

HART Commands: 1 (Device Setup), 3 (Basic Setup), 3 (Reference K-Factor)

NOTE:

Compensated K-Factor can also be read. It will include corrections for entrance effects (Mating Pipe ID), and installation effects.

- A.1 IF the Reference K-Factor is correct, press HOME to return to the main menu.

- A.2 IF the Reference K-Factor is incorrect, enter the correct Reference K-Factor.

Please note you MUST SEND the data whenever changes are made.

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Step 5: Flange Type

A. Verify the correct Flange Type has been entered into the vortex meter. The vortex electronics uses the reference k-factor and flange type to correct for installation effects for high pressure meter bodies (smaller diameter than standard meter body).

HART Commands: 1 (Device Setup), 3 (Basic Setup), 4 (Flange Type)

A.1 IF the Flange Type is correct, press HOME to return to the main menu.

A.2 IF the Flange Type is incorrect, enter the correct Flange Type

Please note you MUST SEND the data whenever changes are made.

Step 6: Mating Pipe I.D.

A. Verify the correct Mating Pipe I.D. has been entered.

HART Commands: 1 (Device Setup), 3 (Basic Setup), 5 (Mating Pipe I.D.)

A.1 IF the Mating Pipe I.D. is correct, press HOME to return to the main menu.

A.2 IF the Mating Pipe I.D. is incorrect, enter the correct Mating Pipe I.D.

Please note you MUST SEND the data whenever changes are made.

Step 7: Primary Variable

A. Verify the correct Primary Variable has been selected (i.e. Volume, Mass, Velocity, or Process Temperature).

HART Commands: 1 (Device Setup), 3 Basic Setup), 6 (Variable Mapping), 1 (Primary Variable)

A.1 IF the Primary Variable is correct, press HOME to return to the main menu.

A.2 IF the Primary Variable is incorrect, select the correct Primary Variable.

Please note you MUST SEND the data whenever changes are made.

Step 8: Primary Variable Units

A. Verify the correct Primary Variable Unit has been selected (i.e. lb/hr, lb/sec, kg/hr, etc).

HART Commands: 1 (Device Setup), 3 (Basic Setup), 7 (PV Units)

A.1 IF the PV Unit is correct, press HOME to return to the main menu.

A.2 IF the PV Unit is incorrect, select the correct PV Unit.

Please note you MUST SEND the data whenever changes are made.

Step 9: Range Values

A. Verify the correct Range Values (4 and 20 mA points) have been selected.

HART Commands: 1 (Device Setup), 3 (Basic Setup), 8 (Range Values)

1 – URV (20 mA)

2 – LRV (4 mA)

A.1 IF the Range Values are correct, press HOME to return to the main menu.

A.2 IF the Range Values are incorrect, enter the correct range values.

Please note you MUST SEND the data whenever changes are made.

Step 10: Signal Processing

A. The last step in performing a basic configuration is executing an Auto Adjust Filter (Optimize Flow Range in AMS Device Manager). However, since this step is simply to verify the basic configuration and that the individual filters may have been customized for your particular application, you should go to the following and record the values present.

HART Commands: 1 (Device Setup), 4 (Detailed Setup) 3 (Signal Processing), 2 (Manual Filter Adjust)

3 – Low Flow Cutoff _____

4 – Lowpass Filter _____

5 – Trigger Level _____

After selecting the each filter, press OK to view the value and record it, and then press ABORT to leave the screen without making any changes.

Technical Note

00840-0300-4004, Rev AA

June 2010

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Procedure II. Electronics Verification through Flow Simulation

NOTE:

In order for the Flow Simulation Function to operate, Primary Variable must be set to Velocity Flow, Volume Flow, or Mass Flow. If PV is set to Process Temperature, it should be temporarily mapped to the flowrate of interest.

NOTE:

For Use Case II - 8800D Vortex meter with MTA Option using Process Fluid of T-comp Sat Steam, the Process Fluid should be changed to Gas/Steam before running a flow simulation.

HART Commands: 1 (Device Setup), 3 (Basic Setup), 2 (Process Config), 2 (Process Fluid)

Please note you MUST SEND the data whenever changes are made.

Refer to "Appendix A: Electronics Verification Form" on page 8 for a Verification Form to be filled out as part of this exercise. You may want to fill out the "expected flowrate" section before beginning Step 1.

Step 1: Read calculated Shedding frequency at URV.

HART Commands: 1 (Device Setup), 2 (Diagnostics and Service), 7 (Shedding Freq at URV).

Step 2: Enter Internal Flow Simulation: Fixed flow, % of range

HART Commands: 1 (Device Setup), 2 (Diagnostics and Service), 4 (Flow Simulation), 3 (Configure Flow Simulation), 1 (Internal), 1 (Fixed Flow), 1 (% of Range)

Step 3: Enter 50% flow using keypad

Step 4: Verify that flow rate output is 50% of full scale

HART Commands: 1 (Device Setup), 2 (Diagnostics and Service), 4 (Flow Simulation), 1 (Flow)

- A. IF the flow rate output is 50% of full scale, the electronics are working properly.
- B. IF the flow rate output is not 50% of full scale, See Troubleshooting guide for Electronics or Section 5 of the Reference Manual.

Step 5: Verify that Frequency = 1/2 Calculated Shedding Frequency at URV

HART Commands: 1 (Device Setup), 2 (Diagnostics and Service), 4 (Flow Simulation), 2 (Shed Freq)

Optional: Verify shedding frequency from internal signal generator is the same as displayed on handheld communicator or AMS Device Manager. This can be accomplished by connecting a device such as a Fluke multi-meter to the test points behind the display labeled "TP1" and Ground (using the universal ground symbol). Connect the positive lead of the digital multi-meter to TP1 and the negative lead to the Ground lug. The frequencies should match to a plant specified tolerance that is no less than the tolerance of the device used to read the frequency.

- A. IF the shedding frequency is 50% of full scale, the electronics are working properly
- B. IF the shedding frequency is not 50% of full scale, See Troubleshooting Guide for Electronics or Section 5 of the Reference Manual.

Step 6: Exit Simulation, and enable normal operation

HART Commands: 1 (Device Setup), 2 (Diagnostics and Service), 4 (Flow Simulation), 4 (Enable Normal Flow)

NOTE:

If the Process Fluid had been changed to Gas/Steam as required by Use Case II, return the Process Fluid to T-Comp Sat Steam.

HART Commands: 1 (Device Setup), 3 (Basic Setup), 2 (Process Config), 2 (Process Fluid)

Please note you MUST SEND the data whenever changes are made.

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Procedure III. Vortex Sensor Verification

Step 1: Signal-to-Trigger Level

- A. Read Signal-to-Trigger (Sig/Tr) Level under normal flowing conditions

HART Commands: 1 (Device Setup), 4 (Detailed Setup), 3 (Signal Processing), 1 (Optimize Flow Range), 3 (Sig/Tr)

- A.1 IF the Signal-to-Trigger Level is >4, Sensor is assured to be Healthy.

NOTE:

Signal-to-Trigger level will vary even at steady flow. Verify that average of several readings remain above 4.

- A.2 IF the Signal-to-Trigger Level is <4, See Appendix B

Procedure IV: Temperature Sensor Verification (For MTA Option Only)

Typically, temperature sensors and temperature transmitters are verified as individual units. However, due to the Rosemount 8800D design that uses a Type N special limits thermocouple and a custom interface between the thermocouple and the electronics, best practice is to verify the components as a system.

Step 1: Remove thermocouple from meter body

- A. Turn off power to the Rosemount 8800D.
- B. Remove the thermocouple from the meter body by using a 1/2-inch open wrench.

NOTE:

Use plant approved procedure for removing a temperature sensor from a thermowell.

- C. Remove the thermocouple from the electronics by using a 2.5 mm allen wrench to remove the cap head screw from the electronics.
- D. Gently pull the thermocouple connector from the electronics.

Step 2: Remove electronics housing from the meter body

NOTE:

If removing the electronics housing is not desired, a spare set of electronics may be used for temperature sensor verification.

- A. Turn off the power to the Rosemount 8800D.
- B. Disconnect the wires and conduit from the housing.
- C. Loosen the screw on the support tube access cover if present.
- D. Remove the access cover (if applicable).
- E. Use a 5/32-inch hex wrench to loosen the housing rotation screws (at the base of the electronics housing) by turning the screws clockwise (inward) until they clear the bracket.
- F. Slowly pull the electronics housing no more than 1.5 in. (40 mm) from the top of the support tube.

NOTE:

Damage to the sensor cable may occur if the sensor cable is stressed.

- G. Loosen the sensor cable nut from the housing with a 5/16-in. open end wrench.

Step 3: Reconnect thermocouple to electronics

- A. Insert the thermocouple connector into the electronics housing using care to align the pin and the cap head screw.
- B. Tighten cap screw with 2.5 mm allen wrench.

Step 4: Bring thermocouple and electronics assembly to the designated temperature sensor calibrator or precision liquid bath

NOTE:

System accuracy shall be no less than ± 0.025 °C (± 0.045 °F).

System stability shall be no less than ± 0.025 °C (± 0.045 °F). Extreme care should be taken that the calibration source is operating properly and within specifications.

- A. Connect power to the Rosemount 8800D.

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00840-0300-4004, Rev AA

June 2010

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Step 5: Set temperature sensor calibrator or precision liquid bath to a set point of 100 °C (212 °F)

- A. IF Process Temperature value in the electronics matches the reference temperature sensor within 2 °C (4 °F), then the thermocouple is healthy and within specifications.
- B. IF Process Temperature value in the electronics matches the reference temperature sensor within 2 °C (4 °F), then repeat with a new electronics and thermocouple to verify the calibration source.
 - B.1. IF the new set of electronics and thermocouple works, then contact your local Rosemount representative for assistance with returning the unit to the factory.
 - B.2. IF the new set also fails, then verify the calibration source.

HART Command: 1 (Device Setup), 1 (Process Variables), 4 (View Other Variables), 9 (Process Temperature)

Procedure V: Perform Density Test Calculation (For Use Case II Only)

For Use Case II – copy from above, the electronics verification was performed using a fixed process density. When the device is in Tcomp Sat Steam mode, the process density is dynamically calculated from the measured process temperature. This procedure will verify that the electronics can calculate the corresponding density of saturated steam for given process temperatures.

Step 1: Verify Process Fluid is set to Tcomp Sat Steam

HART Commands: 1 (Device Setup), 3 (Basic Setup), 2 (Process Config), 2 (Process Fluid)

Please note you MUST SEND the data whenever changes are made.

Step 2: Enter Density Test Calculation

HART Commands: 1 (Device Setup), 2 (Diagnostics and Service), 1 (Test/Status), 3 (Density Test Calc)

Step 3: Enter a process temperature of interest between 80-320 °C (176-608 °F)

Step 4: Compare calculated density to ASME Saturated Steam Table found in APPENDIX C

Procedure VI: Meter Body/Shedder Bar Verification (Required)

NOTE:

Shedder Bar inspection is not required in the vast majority of applications. It is very unusual that a vortex flowmeter will require re-calibration for shedder bar wear in normal applications. (Vortex meters count the frequency of shedding which is proportional to the fluid velocity – and is not highly sensitive to edge sharpness). Exceptions to this are highly corrosive applications, or applications with high levels of suspended solids. Wear in these types of applications may be significant enough to cause a shift in the meters K-factor, and require re-calibration. This is an unusual circumstance.

If shedder bar wear is suspected, the following steps can be followed to determine if it is significant enough to warrant re-calibration.

Step 1: Remove meter from process line.

Step 2: Inspect Shedder Bar leading edge for sharpness.

A. Visual Inspection

This requirement may be considered satisfied by visual inspection if the edge does not seem to reflect a beam of light when viewed with an unaided eye.

Procedure VII: Wet Calibration (If Required)

If the criteria of Procedures I through VI cannot be met or completed successfully the meter body should be re-calibrated by a certified Flow Test lab. If convenient, the meter can be sent back to the Rosemount Factory in Eden Prairie, MN, USA or a local Rosemount Service center that supports vortex calibration. If this is impracticable due to location, all developed industrial nations will have National Technical Standard-certified Flow Labs which may perform this service.

APPENDIX A: ELECTRONICS VERIFICATION FORM

Procedure Steps – Readings are taken while the transmitter is in Flow Simulation mode.

A. Read shedding frequency in the transmitter (1,1,4,6)

Frequency = _____ Hz

B. Read Flow Rate output (1,1,1)

Flow = _____

C. Read Compensated K-factor (1,4,1,1,1)

K Compensated = _____

D. Calculate expected (Theoretical) flow rate for given frequency.

Calculate the theoretical volumetric or mass flow rate as follows:

$$Q_{vol} = F(\text{Hz}) / (K \times Cx)$$

$$Q_{mass} = F(\text{Hz}) \times \rho / (K \times Cx)$$

Where:

F(Hz) = Test Frequency

K = Compensated K-Factor (From 475)

ρ = Density at Operating Condition (From 475)

Cx = Unit Conversion factor (See Table 1 below)

Calculate a base volumetric flow rate (i.e. SCFM or NCMH) as follows:

$$Q_{basevol} = F(\text{Hz}) \times ((\text{Density Ratio}) / (K \times Cx))$$

Where:

$$\text{Density Ratio} = \frac{\text{density at actual (flowing conditions)}}{\text{density at base (standard or normal) conditions}}$$

Density Ratio (1,3,2,4,1,1)

TABLE 1. Unit Conversion Factors

Units (Actual)	Conversion Factor (Cx)	Units (Actual)	Conversion Factor (Cx)
gal/s	1.00000 E+00	CuMtr/h	7.33811 E-02
gal/m	1.66667 E-02	CuFt/m	1.24675 E-01
gal/h	2.77778 E-04	CuFt/h	2.07792 E-03
Impgal/s	1.20095 E+00	bb/h	1.16667 E-02
Impgal/m	2.00158 E-02	kg/s	(2.64172 E-01)/Density
Impgal/h	3.33597 E-04	kg/h	(7.33811 E-02)/Density
L/s	2.64172 E-01	lb/h	(2.07792 E-03)/Density
L/m	4.40287 E-03	shTon/h	(1.03896 E-06)/Density
L/h	7.33811 E-05	mTon/h	(7.33811 E-05)/Density
CuMtr/m	4.40287 E-03	SPECIAL	Cx/(Special Unit Conversion Number)

E. Verify that calculated flow matches flow output from the transmitter

E.1. IF flows don't match, and Basic Configuration is re-verified as correct – electronics should be replaced

F. Verify 4-20 mA Output

For a given input frequency F(Hz), and K-factor(compensated), find output current I:

Where: LRV = Lower Range Value (User unit)

URV = Upper Range Value (User unit)

$$I = \left(\left[\frac{F(\text{Hz}) / (K \times Cx) - \text{LRV}}{\text{URV} - \text{LRV}} \right] \times 16 \right) \div 4$$

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00840-0300-4004, Rev AA

June 2010

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APPENDIX B: VORTEX SENSOR HEALTH VERIFICATION

Verifying Vortex Sensor if Signal-to-Trigger Level is less than 4

STEP 1: Check Sensor and sensor lead wire for shorts

- Isolated from the process
- Can be checked with no process shutdown
- Single sensor for all designs, line sizes
- Can be replaced in the field without impacting calibration and without breaking the process seal⁽¹⁾

PROCEDURE STEPS:

- Loosen the three housing rotation screws with Allen head wrench.
- Slowly pull electronics housing - NOT MORE THAN 2 INCHES from top of support tube (To avoid damage to lead wire).
- Loosen and remove sensor cable nut (using a $\frac{5}{16}$ -in. wrench)
- Using Multi-meter touching co-axial connector pin (and grounded to meter body), verify that sensor impedance is > 1 megaohm.
- If multi-meter reads short, sensor must be replaced*. See Reference Manual for details.

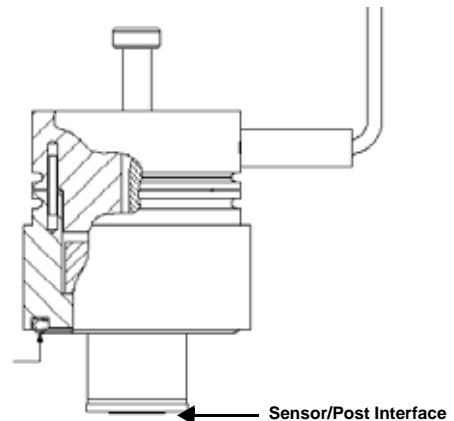
A special connector has been developed to make this measurement easier. A part is available from www.pasternack.com and is part number PE36517-18. A picture of the connector can be found below:



⁽¹⁾ Although no process seal is broken, it is recommended that the pipe be de-pressurized when replacing sensors



STEP 2: Check Sensor/Post Interface for damage



PROCEDURE STEPS:

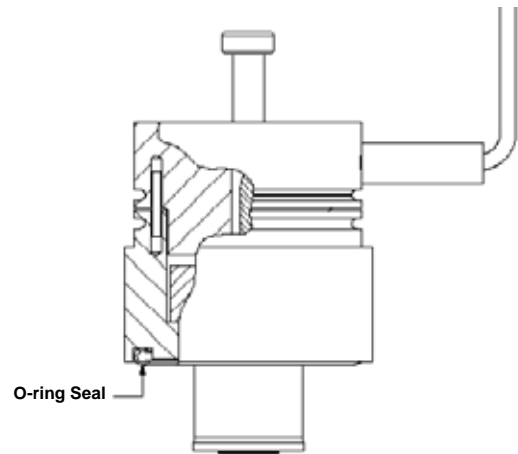
- Sensor should only be checked for mechanical damage if all other potential sources have been checked first.
- Sensor/Post interface is important, and can be damaged when removing or inserting sensors.
- Sensor should fit on post snugly. If sensor can be removed (pulled) from post easily, it likely has been damaged from a slug flow or water hammer, and should be replaced with a new sensor⁽¹⁾.
- Sensor/Post interface should be round. If damaged, it may be slightly 'ovaed'.
- Sensors should not be removed and reinstalled more than once, due to the potential for damage.

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Replacing Sensor - Safety Considerations

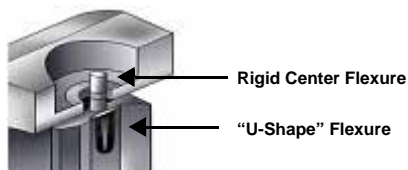
- Replaceable sensor also serves as a secondary seal up to Flange Rating with metal O-ring
- Recommended procedure for replacing a sensor is to de-pressurize the flow process

Warning on the sensor nut retaining replaceable sensor:



Flexure System Designed for Safety

- Rigid Center Flexure designed to operate indefinitely at meter design limits
- "U-Shape" Flexure will fail first in the even of corrosion.



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00840-0300-4004, Rev AA

June 2010

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TABLE 2. ASME Saturated Steam Table (English Units)

Temperature (°F)	Density (lbs/ft ³)	Temperature (°F)	Density (lbs/ft ³)	Temperature (°F)	Density (lbs/ft ³)
176	0.0183	325	0.2175	475	1.1658
180	0.0199	330	0.2322	480	1.2237
185	0.0221	335	0.2477	485	1.2842
190	0.0244	340	0.2640	490	1.3473
195	0.0270	345	0.2812	495	1.4131
200	0.0297	350	0.2992	500	1.4817
205	0.0327	355	0.3182	505	1.5532
210	0.0360	360	0.3381	510	1.6279
215	0.0394	365	0.3591	515	1.7058
220	0.0432	370	0.3810	520	1.7871
225	0.0472	375	0.4041	525	1.8720
230	0.0516	380	0.4282	530	1.9606
235	0.0563	385	0.4535	535	2.0532
240	0.0613	390	0.4800	540	2.1499
245	0.0666	395	0.5077	545	2.2510
250	0.0724	400	0.5368	550	2.3567
255	0.0785	405	0.5671	555	2.4673
260	0.0850	410	0.5989	560	2.5830
265	0.0920	415	0.6321	565	2.7042
270	0.0994	420	0.6668	570	2.8312
275	0.1073	425	0.7031	575	2.9643
280	0.1157	430	0.7409	580	3.1040
285	0.1246	435	0.7805	585	3.2508
290	0.1340	440	0.8218	590	3.4051
295	0.1441	445	0.8649	595	3.5675
300	0.1547	450	0.9099	600	3.7387
305	0.1659	455	0.9568	605	3.9194
310	0.1777	460	1.0058	608	4.0329
315	0.1903	465	1.0569		
320	0.2035	470	1.1102		

TABLE 3. ASME Saturated Steam Table (SI Units)

Temperature (°C)	Density (kg/m ³)	Temperature (°C)	Density (kg/m ³)	Temperature (°C)	Density (kg/m ³)
80	0.2933	165	3.6711	250	19.9850
85	0.3535	170	4.1228	255	21.7884
90	0.4235	175	4.6180	260	23.7339
95	0.5045	180	5.1599	265	25.8332
100	0.5977	185	5.7519	270	28.0994
105	0.7046	190	6.3973	275	30.5473
110	0.8265	195	7.1001	280	33.1939
115	0.9650	200	7.8641	285	36.0581
120	1.1217	205	8.6937	290	39.1617
125	1.2983	210	9.5934	295	42.5300
130	1.4967	215	10.5680	300	46.1921
135	1.7188	220	11.6228	305	50.1827
140	1.9666	225	12.7634	310	54.5437
145	2.2423	230	13.9958	315	59.3274
150	2.5481	235	15.3267	320	64.6003
155	2.8865	240	16.7632		
160	3.2599	245	18.3131		

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**Emerson Process Management
Rosemount Measurement**
8200 Market Boulevard
Chanhassen MN 55317 USA
Tel (USA) 1 800 999 9307
Tel (International) +1 952 906 8888
Fax +1 952 949 7001

**Emerson Process Management
Flow**
Neonstraat 1
6718 WX Ede
The Netherlands
T +31 (0)318 495555
F +31(0) 318 495556

Emerson FZE
P.O. Box 17033
Jebel Ali Free Zone
Dubai UAE
Tel +971 4 811 8100
Fax +971 4 886 5465

**Emerson Process Management Asia Pacific
Pte Ltd**
1 Pandan Crescent
Singapore 128461
Tel +65 6777 8211
Fax +65 6777 0947
Service Support Hotline : +65 6770 8711
Email : Enquiries@AP.EmersonProcess.com