INSTRUCTOR MANUAL: STUDENT ACTIVITY - INSTRUMENT UNCERTAINTY

Uncertainty Allowance	Variable	Process Interface	Process Measurement (Primary Element)	Ambient or Process Environment	Signal Interfaces / Cabling	Signal Conditioning / Processing	Display or Actuation
(1) **Process Measurement Effects**	Temp						
	Flow	Density/temp					
	Level						
(2) **Instrument Uncertainty**	Temp		RTD or T/C reference accuracy				
	Flow						
	Level						

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(3) **Calibration Uncertainty**	Temp			Temperature / pressure compensation	M&TE accuracy		Calibration of:
	Flow						
	Level		DP transmitter calibration				
(4) **Other Uncertainties**	Temp					Computational uncertainty (e.g., characterization, temperature compensation, or modeling)	
	Flow				Insulation resistance in accident environment		
	Level						

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NOTES:

The objectives of this student activity are to:

1. Develop an overall understanding of the various uncertainty allowances that might need to be considered in a process measurement, and

2. Recall and reinforce some of the process instrument attributes and characteristics discussed in Session 7 (I&C components).

For this exercise, we will consider 4 **uncertainty allowances** for measuring temperature, flow, and level:

1. **Process Measurement Effects** - Uncertainties induced by the physical characteristics or properties of the process that is being measured.[1]

2. **Instrument Uncertainty** – Uncertainties associated directly with the instrument or module (reference accuracy, temperature effects, pressure effects, drift, module power supply variations, RTD accuracy confirmation, accident environmental effects.

3. **Calibration Uncertainty** - Calibration is performed to verify that equipment performs to its specifications and to eliminate/minimize bias uncertainties associated with installation and service (for example, bias from static head effects or density compensation). Calibration uncertainty refers to the uncertainties introduced into the instrument channel during the calibration process. This includes uncertainties introduced by test equipment, procedures, and personnel.

   Temperature effects: Calibration of an instrument or module must be performed at approximately the same temperature, so that temperature effects between calibrations are minimized.

   Method of calibration: Depending on the method of calibration or performance verification, an allowance for calibration tolerance may need to be included in the setpoint uncertainty calculation. If the method of calibration or performance verification verifies all attributes of reference accuracy (**linearity, hysteresis, dead band, and repeatability**) and the calibration tolerance is ≤ the reference accuracy, then the calibration tolerance need not be included in the total instrument channel uncertainty. To verify the four attributes of reference accuracy, an instrument channel should be exercised up and down several times (typically "3-up-and-3-down") to verify reference accuracy. Then, the calibration or performance verification has explicitly verified the channel performance is within the allowance for the channel's reference accuracy in the uncertainty calculation. If the method of calibration or performance monitoring verifies all attributes of the reference accuracy and the calibration tolerance is larger than the reference accuracy, the larger value for the calibration tolerance may be substituted for the reference accuracy in the uncertainty calculation, as opposed to inclusion of the calibration tolerance as a separate term. In these cases, the calibration tolerance is the term used to represent reference accuracy in the test's performance, and it does not represent a separate uncertainty term in the

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[1] For example, ASME MFC-3M, *Measurement of Fluid Flow in Pipes Using Orifices, Nozzles, and Venturi* states that, if the minimum upstream and downstream straight run lengths are met, the resultant flow measurement uncertainty for the piping configuration (not including channel equipment uncertainty) should be assumed to be 0.5% of the discharge coefficient. If the minimum criteria cannot be met, additional uncertainty (say at least 0.5%) should be assumed for conservatism based on an evaluation of the piping configuration and field measurement data, if available.

setpoint uncertainty calculation.[2]

4. **Other Uncertainties**, such as effects of cable insulation resistance changes under accident conditions.

The ISA 67.04.02 Figure (block diagram) will be used as a "road map" for discussing these uncertainty allowances.

This table is for instructional purposes only, and does not represent a comprehensive checklist.

Note also that the uncertainty categories could be interpreted differently. For example, the effect of the measured process on the primary element (such as the effect of flow conditions upstream of an orifice) is considered by some to be included as an Instrument (primary element) uncertainty, rather than a Process Measurement Effect. But the important thing is to identify the uncertainty, and evaluate its effects, no matter how the uncertainty is categorized.

ACTION:

The students will be given the ISA 67.04.02 block diagram and a table identifying the four types of uncertainty allowances associated with measurement of temperature, flow, and level (i.e., the first 2 columns of the table will be filled in). The students will identify as many of the specific sources of error as they can, by filling in the remaining applicable blank columns. The instructor may start the exercise with one or two examples, focusing on the block diagram.

After the students have had time to provide input on their tables, the class will fill in a common table with the collective entries. The results will then be discussed and supplemented as necessary.

Note: Unless the student has some previous experience with instrumentation, it is not likely that all of the responses shown on the Instructor Manual Table will be identified by the students. It is expected that this should be a learning experience. There may be some uncertainty elements that are not associated with specific components discussed in Session 7. Any such new items will be highlighted.

[2] For example, if the vendor's stated reference accuracy for a particular module is 0.25%, but the calibration tolerance used in the procedure is 0.5%, the value of 0.5% may be used for the reference accuracy of the module in the setpoint uncertainty calculation with no additional allowance for calibration tolerance.