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AMS Fact Sheet: Pressure Transmitter Response Time Testing Using the Noise Analysis Technique

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1.0 INTRODUCTION

This fact sheet provides the details of AMS testing for response time of pressure transmitters in nuclear power plants. The primary method used by AMS for measuring pressure transmitter response time is the “noise analysis” technique which is based on monitoring the natural fluctuations (noise) that exist at the output of pressure transmitters while the plant is operating. AMS model OLM-8 test equipment can measure the response time of up to 8 transmitters at a time in as little as 30 minutes per test.

The conventional method for response time testing of pressure transmitters in nuclear power plants is referred to as the “ramp test.” The response time of pressure transmitters can also be obtained using a step pressure signal. However, the ramp test method is more often used because most accident analyses in nuclear power plants assume pressure transients that resemble a ramp signal more so than a step signal. As for the response time measurements, the step, ramp, or noise analysis techniques normally yield comparable results provided that the assumptions about the dynamic model of the transmitter and the characteristics of the input test signal are satisfied.

Details of the step, ramp, and noise tests are presented in two research reports which AMS wrote for the U.S. Nuclear Regulatory Commission (NRC). These reports are referred to as NUREG/CR-5383 and NUREG/CR-5851 and describe the bases for the techniques presented in this Fact Sheet.

2.0 CONVENTIONAL RAMP METHOD FOR SENSOR RESPONSE TIME TESTING

The ramp test is typically performed using a hydraulic ramp generator. The pressure test signal, as generated by this equipment, is fed to the transmitter under test and simultaneously to a high-speed reference transmitter. The outputs of the two transmitters are recorded and used to identify the response time of the transmitter under test. Figure 1 illustrates how the ramp equipment is used and how the response time (τ) of the transmitter is determined. Figure 1 also shows a picture of the ramp test equipment and software provided by AMS to the nuclear power industry.

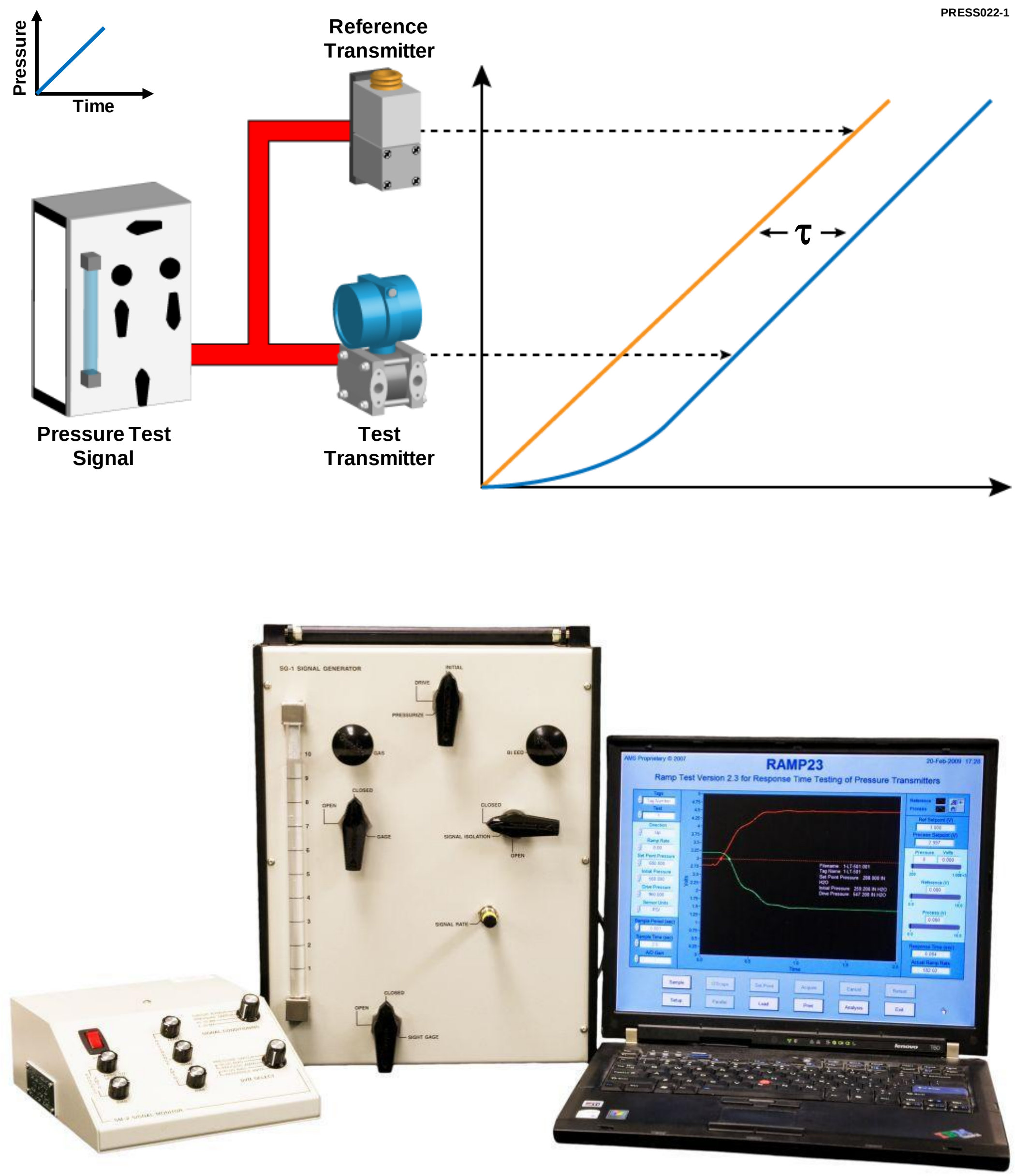

Figure 1. Equipment Setup for Ramp Tests of Pressure Transmitters (top) with AMS Ramp Test Equipment and Software (bottom)

3.0 NOISE ANALYSIS TECHNIQUE

The noise analysis technique uses the output of a pressure transmitter (sampled at 1000 Hz or more) to provide its dynamic response. It is based on monitoring the natural fluctuations (noise) that exist at the output of sensors while the plant is operating (Figure 2). These fluctuations are due to turbulence induced by the flow of water in the system, random heat transfer in the core, and other naturally occurring phenomena. The noise is extracted from the sensor output by removing the DC component of the signal and amplifying the AC component. The noise data acquisition is advantageous in nuclear power plant applications because it is a passive test that can be performed remotely from the control room area or instrumentation cabinets, does not interfere with plant operation, does not involve radiation exposure to the test personnel, and can be performed simultaneously on several sensors at a time.

Figure 3 shows the AMS equipment setup for noise data acquisition in a nuclear power plant. This equipment consists of a signal conditioning module referred to as the AMS Model OLM-8 and a data acquisition computer with a 24-bit A/D. The equipment is set up in the control room area where the transmitter output signals can be accessed through the current loops in the plant instrumentation cabinets. The AMS equipment is configured with high input impedance and a power off circuit such that it does not disturb plant operation while the test is performed.

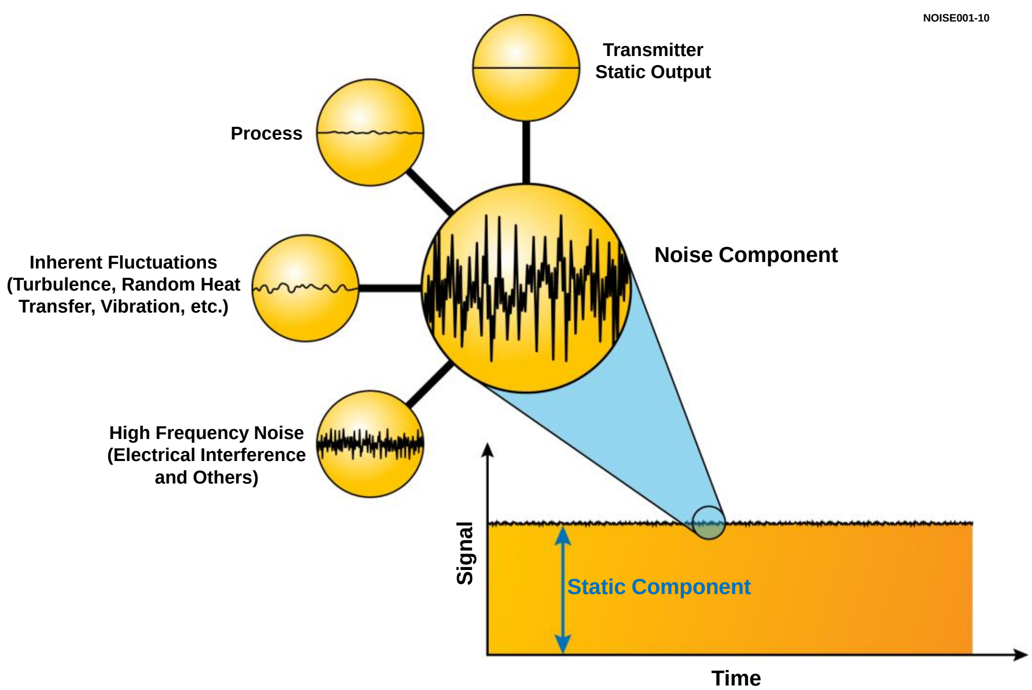

Figure 2. Illustration of Noise on the DC Output of a Pressure Transmitter

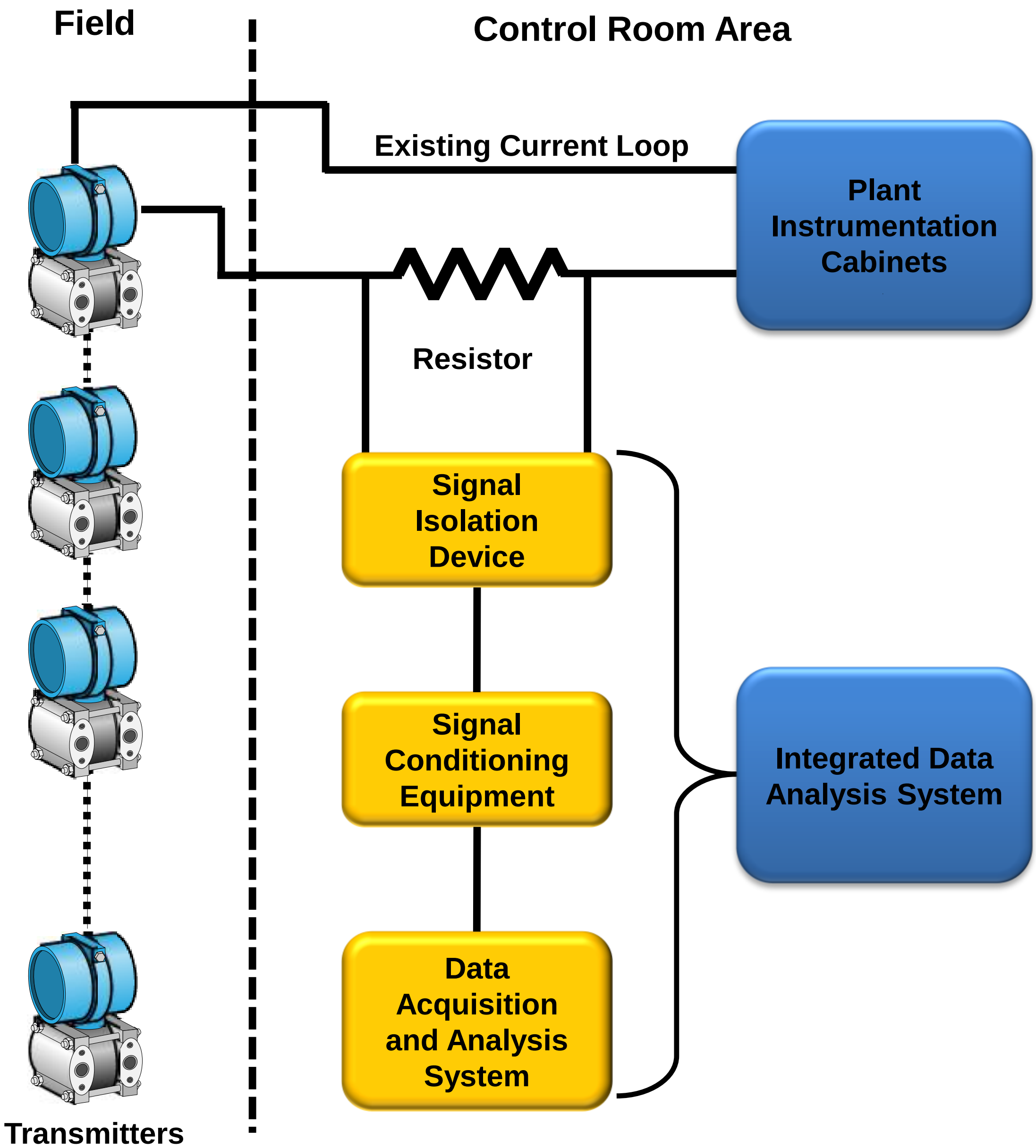

Figure 3. AMS Equipment Setup for In-Plant Testing of Pressure Transmitters Using the Noise Analysis Technique

3.1 DATA ANALYSIS

The analysis of noise data is performed in the time domain and frequency domain, and is based on the assumption that the dynamic characteristics of the sensor are linear and the input noise signal (i.e., the process fluctuations) has proper spectral characteristics.

For time domain analysis of the noise data, autoregressive (AR) modeling techniques are used. The noise data records for each sensor are fit to a general autoregressive model of order "***n***". The fit of the noise data record will identify the coefficients of the model. These coefficients are then used to obtain dynamic descriptors such as the impulse response, step response, and ramp response of the sensors under test.

In frequency domain analysis, the power spectral density (PSD) of the noise signal is generated using a Fast Fourier Transform (FFT) algorithm. After the PSD is obtained, a mathematical model that is appropriate for the sensor under test is fit to the PSD to yield model parameters that are then used to calculate the dynamic behavior of the sensor in terms of response time. Figure 4 illustrates the general principle for the determination of response time from the PSD of a first order system.

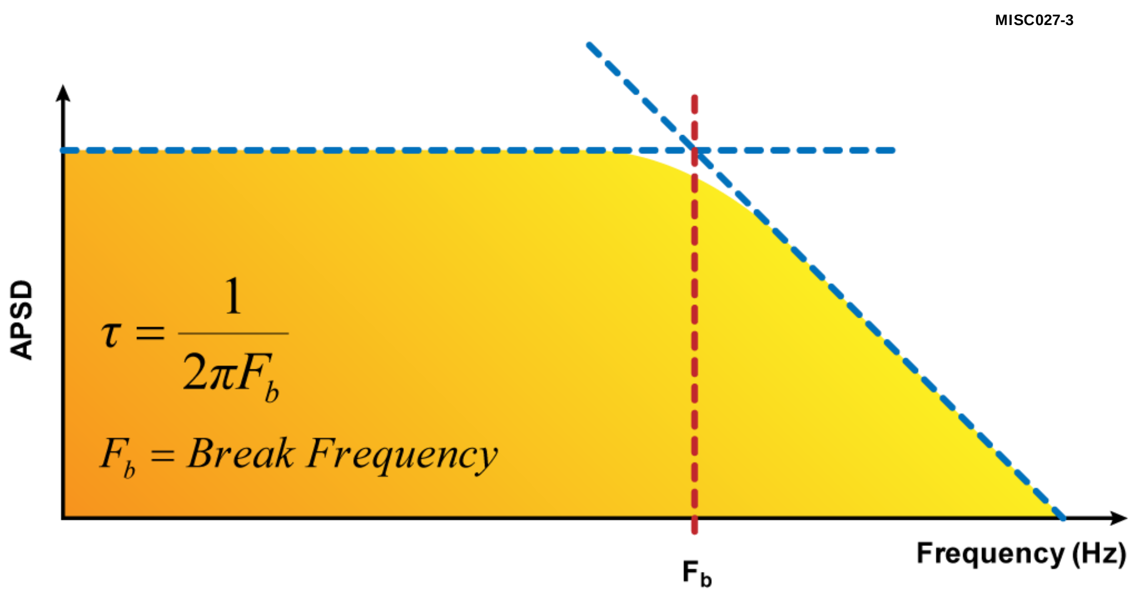

Figure 4. Illustration of Frequency of Response of a First Order System

It should be noted that the PSDs of nuclear plant pressure transmitters have various shapes and are often dependent on the plant, transmitter installation and service, process conditions, and other effects. Figure 5 shows examples of a few typical nuclear plant PSDs. The PSDs shown are for steam generator level, reactor water clean-up flow, and pressurizer pressure transmitters.

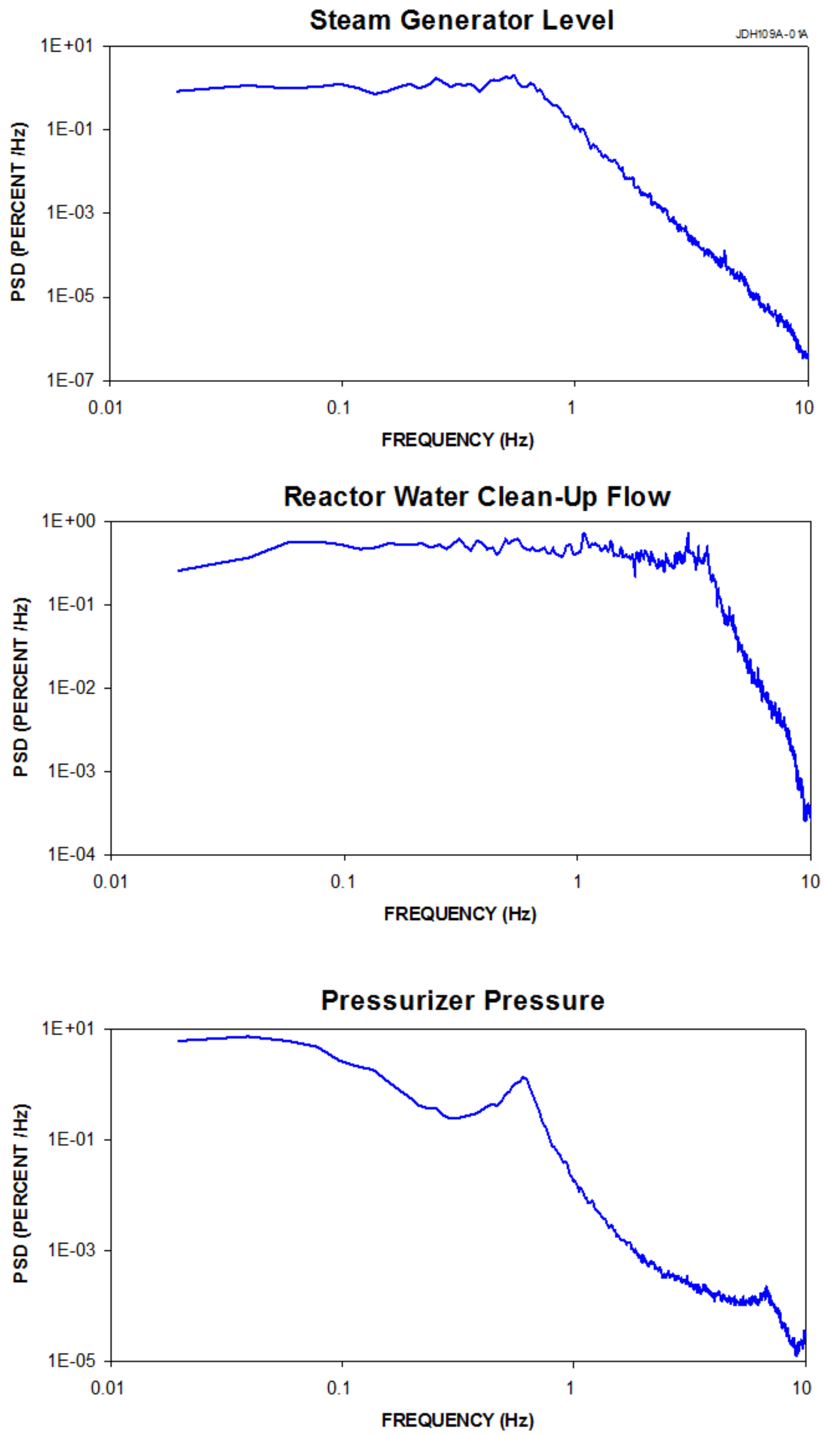

Figure 5. Examples of PSDs of Nuclear Plant Pressure Transmitters

Sensing lines that are filled with process fluid (usually water) can affect the response time of a pressure sensing system and contribute to delays and response time degradation, especially if the sensing line develops any significant blockages or voids. Therefore, it is important to include the effect of sensing lines on the overall response time of a pressure sensing system. The noise analysis technique provides the response time of not only the pressure transmitter but also accounts for any significant effect of sensing line blockages, voids, valve issues, and other problems on the response time of pressure sensing system. This is illustrated in Figure 6 showing the impact of a sensing line blockage on the process fluctuations which would be experienced by a transmitter.

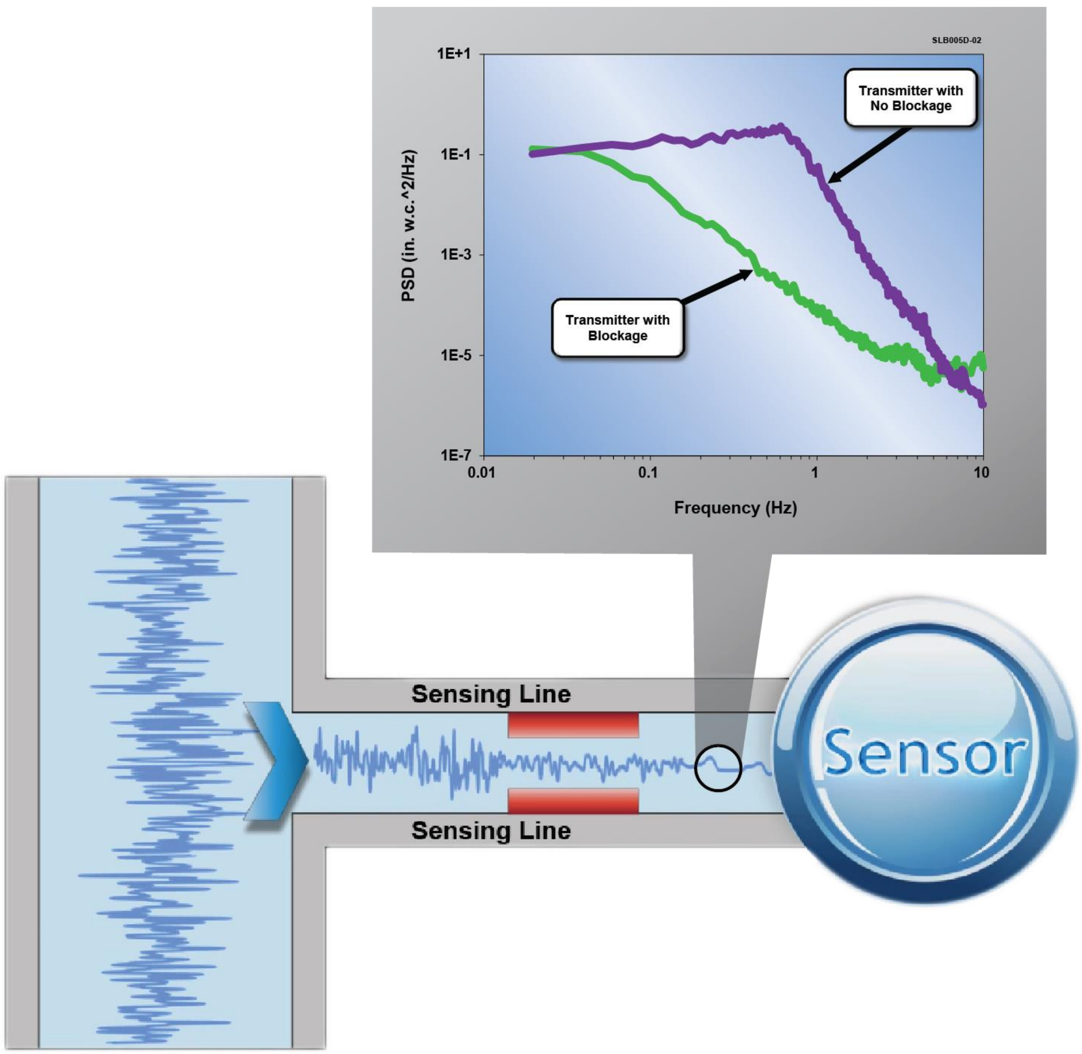

Figure 6. Illustration of the Effects of Sensing Line Blockage on Sensor Response Time

4.0 IN-SITU RESPONSE TIME TESTING OF CONTAINMENT PRESSURE AND TANK LEVEL TRANSMITTERS

Some pressure transmitters, such as containment pressure transmitters and water storage tank level transmitters do not normally experience process pressure fluctuations. Therefore, these transmitters cannot be tested for response time using the traditional noise analysis procedure. For these transmitters, a special procedure was developed that enables one to take advantage of the noise analysis technique to measure the response time in-situ. More specifically, a synthetic noise signal generator was developed by AMS to produce pressure noise signals that are directed to the transmitter while its output is recorded using AMS noise analysis equipment. The output is then analyzed using the noise data technique. This method helps reduce test time and provide more consistent and reliable results when compared to the traditional ramp test technique.

The synthetic noise is generated using a test unit referred to as the AMS Model PNG. This PNG unit is shown in Figure 7. The procedure for response time testing of pressure transmitters using the PNG is outlined below:

1. Connect air supply to the input of the PNG.
2. Plant personnel disconnect the transmitter under test from the process and connect the pressure output of the PNG to the transmitter.
3. Adjust the amplitude of the PNG in order to properly stimulate the transmitter through its full dynamic range.
4. Acquire noise data using AMS noise analysis equipment.
5. Disconnect the air supply from PNG input.
6. Disconnect the PNG output from the transmitter under test.
7. Plant personnel restore the transmitter to normal service.

Upon completion of the test, the noise data is analyzed using the same methods described in this fact sheet. This method has been validated in the laboratory to provide results with comparable accuracies to the noise analysis technique.

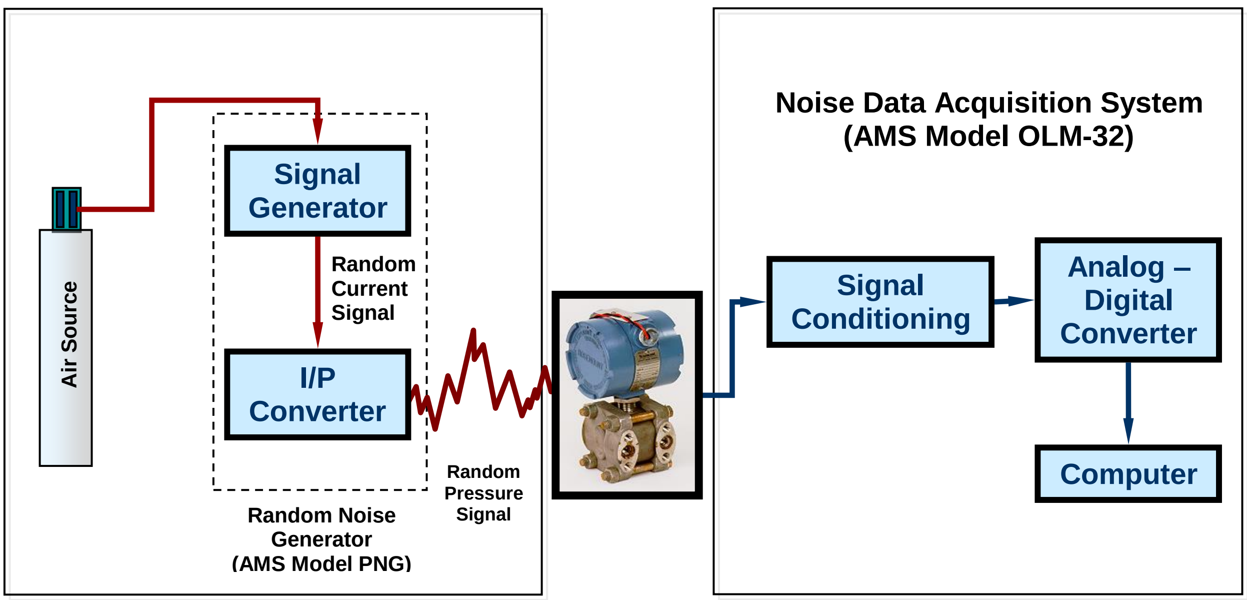

Figure 7. Equipment Setup for Response Time Testing of Containment and Tank Level Pressure Transmitters Using Synthetic Noise Input Data