TECHNICAL NOTE

SQUARE ROOT ERROR INDICATOR GAGE LINE EFFECTS

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INTRODUCTION

There have been reports from field users of the Square Root Error Indicator (SREI) of high levels of indicated square root error (SRE) in natural gas orifice metering runs that, on closer analysis, were found to be spurious. This infrequent phenomena is due to high frequency pulsations or flow turbulence in the metering run causing resonant excitation of the flexible transducer gage lines supplied with the SREI. This technical note has been prepared to:

- acquaint users of the SREI with the underlying physics of gage line resonance,
- describe methods for identifying a resonant gage line condition,
- describe methods for dealing with the effects of resonance, when found, and
- describe a method of correcting the measured SRE when the condition is present.

PURPOSE OF THE SREI

The Square Root Error Indicator (SREI) was developed to aid industry in identifying the presence of low frequency pulsations in orifice runs, and to provide a quantitative readout of the square root error (SRE) that results from that pulsation. SRE is but one of several measurement errors that can result from pulsating flow*; hence, *the SREI should never be used to adjust volume in compensation for pulsation effects*. The readings supplied by the SREI are, however, a useful diagnostic aid in identifying pulsation conditions that are too high for accurate measurement.

BACKGROUND ON SREI GAGE LINE DYNAMICS

The differential pressure transducers used by the SREI must be attached to the orifice taps by use of a gage line and manifold system such as that provided with the SREI package. Unfortunately, any such gage lines have a finite and limited frequency band over which they accurately sense and transmit pressure information. The computational routine within the SREI assumes that (and the error readings are only correct when) there is no distortion of the orifice tap pressure information by the SREI gage lines, i.e., when the pressure signature (static and dynamic pressures) seen by the transducers are precisely the same as those at the orifice taps. The primary source of gage line distortion is the resonant amplification that can occur in the gage line when pulsation frequencies are near one of the acoustical natural frequencies of the gage line.

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* See references at end of text

The frequency response (transfer function) of a typical SREI gage line is illustrated in Figure 1. For the example shown, a flat response is observed up to about 65 Hz, with the first (lowest) resonant frequency at 100 Hz. Two types of problems can be caused by gage line acoustic response:

(1) ΔP measurements (and SREI readings) are valid only for orifice pulsation frequencies up to about 65 percent of the lowest acoustic resonant frequency of the SREI gage lines. Higher pulsation frequencies at the orifice will not be faithfully transmitted to the SREI pressure transducer, and may be amplified or attenuated, depending upon their frequency and the SREI gage line resonant frequencies.

Pt/Po = Pulsation Pressure at Transducer End ÷ Pulsation Pressure at Orifice

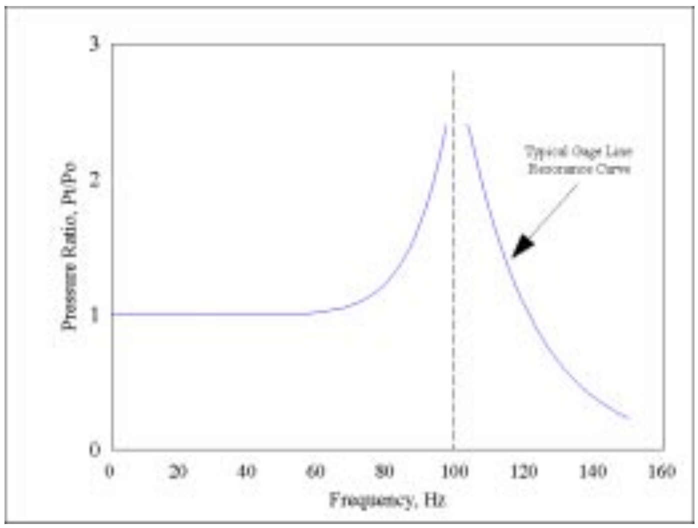

Figure 1.
Typical Frequency Response of a Single, Constant Bore Gage Line

(1) Under some conditions, acoustic frequencies may be excited in the SREI gage lines that are not present in the orifice run. These acoustic resonances are usually generated by high frequency turbulence or pulsation levels in the meter tubes (e.g., from a nearby regulator valve), and occur only at those frequencies that correspond to a length resonance of the gage lines (e.g., 100 Hz for the example shown). If the two gage lines are different in length, then two such resonances may be excited. If these resonances are in the 0 - 200 Hz frequency range, they are processed by the SREI to produce a false square root error reading.

The dynamic response shown in Figure 1 has several important implications when interpreting SREI measurements.

- The range of pulsation frequencies that can be accurately accommodated by the SREI is limited because of the SREI gage lines.

- The resonant frequencies of the SREI gage line/manifold system are related to the tubing lengths, types of manifold, fittings and valves used, gas properties, and the configuration of any branch lines attached. Unless these resonant frequencies are much higher than the pulsation frequencies in the meter tubes, the gage line resonances may distort pulsation signals as seen by the ΔP transducer. In such cases, the SREI will not accurately measure SRE. It is important, therefore, to keep SREI gage lines as short as possible when high frequency pulsations, above about 50 Hz, may be present.

- In field use, if SRE reads near zero, the reading is correct in almost all cases and no SRE problem is present for the flow condition tested. The only potential exception is for the very unusual case where high frequency pulsations exist in the meter tubes that are well above the resonant frequency of the gage line, i.e., in the frequency range of 150 to 200 Hz. More specialized diagnostic techniques and equipment (piezoresistive transducers, spectrum analyzers, etc.) are needed to identify orifice pulsations in this frequency range.

- If a significant square root error is indicated by the SREI, the observed square root error reading may either be correct, exaggerated, or totally false, depending upon the frequencies involved:

  ⇒ Low frequency pulsations (up to about 65% of the gage line resonant frequency) are transmitted correctly by the gage lines resulting in correct SRE indications.

  ⇒ Higher frequency pulsations (near the length acoustic frequency) can be amplified (increased in magnitude) by gage line resonance producing false indications of SRE.

  ⇒ Severe turbulence can excite the gage line into resonance and produce false indications of SRE.

DEALING WITH SREI GAGE LINE DISTORTIONS

In view of these potential gage line problems it is important in using the SREI to:

- Minimize the probability of gage line problems,
- Identify gage line resonances, using appropriate field diagnostic procedures, and
- Eliminate the effect of gage line distortion when it appears.

These topics are discussed in the next paragraphs.

Minimizing the Probability of Gage Line Resonances

Gage line resonant frequencies are inversely proportional to their length. It is important, therefore, to keep the transducer short-coupled to the flanges; i.e., to keep gage lines as short as possible. Most pulsations that affect orifice metering (from compressors, flow past a branch stub, hunting regulators, etc.) are between 0 and 200 Hz, and usually below 100 Hz. The SREI itself is designed to ignore (filter out) pulsations above 200 Hz. It is desirable, therefore, to keep gage line resonant frequencies above 200 Hz, but practical considerations usually make this impossible.

The flexible hose and manifold system provided with the SREI transducer usually exhibit a lower resonant frequency in the range of 100 to 160 Hz, depending on the tap valves used, the orifice flange configuration, gas properties, etc. This gage line system, therefore, will accurately accommodate pulsations up to about 65 to 100 Hz, but can amplify higher pulsation frequencies near the resonances. Other gage line configurations, such as the double-z steel tubes illustrated in Figure 2, can be used to shorten the path between the orifice taps and the transducer. These are not as convenient to use as the hoses provided with the SREI, but can be used to minimize the probability of gage line distortion at those installations where pulsation frequencies up to 100 Hz may be present.

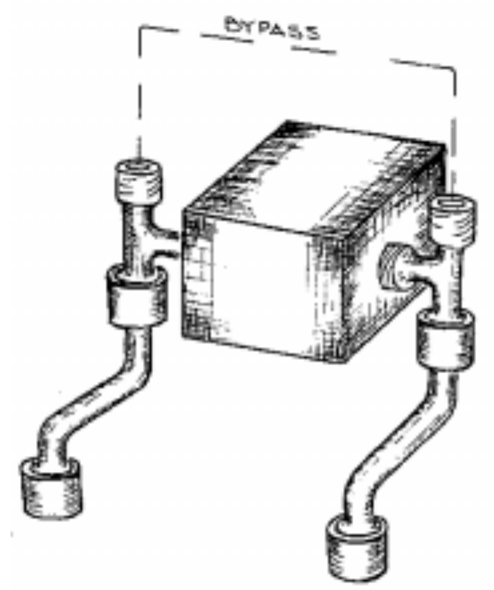

Figure 2.
Double-Z Gage Lines to Accommodate Various Tap Spacing

Identifying Gage Line Resonances

Several techniques are available for identifying the presence of gage line resonance in the field. These usually require the use of additional electronic analysis equipment (e.g., a spectrum analyzer or oscilloscope) capable of resolving pulsation frequency and amplitude over a range of 0 to 200 Hz. These instruments, when attached to the SREI analog output, provide a means of defining pulsation and/or gage line frequencies, and for performing the following diagnostic procedures.

a. Modifying the Gage Line Configuration

Because gage line resonant frequencies in the SREI transducer system are a direct function of the gage line length and configuration, these resonances can be identified in the presence of other pulsation signals. When such resonances are suspected, slight changes to the SREI gage line configuration will cause corresponding changes in the pulsation frequencies, which can be observed with a spectrum analyzer or oscilloscope. The following steps should be followed:

(1) If a significant pulsation error is observed on the SREI, connect a spectrum analyzer to the SREI output terminal and observe the pulsation spectrum. Normally, if gage line resonances are present, they will appear at

frequencies on the order of 100 Hz or above, although this frequency may vary from installation to installation.

(2) If all pulsation frequencies are below 80 Hz, they are probably not gage line resonances and the SRE indications are correct.

(3) To positively identify if gage line resonances are present, change the length of the gage lines (add a stub or use different tubing connectors, such as those shown in Figure 2). If a gage line resonance is present, it will either disappear or shift in frequency because of the new length. If diagnostic testing shows that only gage line resonances are present in the spectrum, then the true SRE is zero. If both gage line resonances and pulsations are present, then the SRE reading is distorted by the resonances. The SRE contribution due to gage line resonance can be eliminated by using the techniques described below.

b. Pinching Gage Line Valves

In some cases, partially closing one or both of the orifice tap valves can eliminate a gage line resonance in the SRE manifold. If such a resonance is suspected, slowly close each of the tap valves connecting the SREI manifold. If the observed pulsation progressively shifts in frequency as the valve is closed (normally to a progressively lower value), then the signal is a gage line resonance.

c. Comparing to Known Resonant Frequencies

After operational experience is gained with the SREI transducer and gage line system, gage line resonances will usually be recognizable without modifying the manifold system, simply by knowing the frequency range over which these resonances occur.

Correcting for Gage Line Resonances

The contribution of gage line resonance to total measured SRE can be corrected mathematically by using these procedures:

(1) For SREI's with an adjustable internal filter, set the filter cut-off just below the SREI gage line frequency. This will eliminate all frequencies above the filter setting.

(2) If the SRE does not have a filter, the SREI gage line contribution can be calculated and subtracted from the SRE value read using the following process:

- Read the gage line resonant amplitude(s) from the spectrum analyzer.
- Read the average differential pressure from the orifice meter.
- Calculate the component of SRE produced by the gage line resonance frequencies from the following equation:

$$SRE = \frac{1}{16}\left[\left(\frac{\delta p_1}{\overline{\Delta P}}\right)^2 + \left(\frac{\delta p_2}{\overline{\Delta P}}\right)^2 + \ldots\left(\frac{\delta p_n}{\overline{\Delta P}}\right)^2\right] \times 100\%$$

where: δp_1, δp_2, … δp_n are the first n zero-to-peak amplitudes of observed gage line resonances on a spectrum analyzer, and

$\overline{\Delta P}$ is the average measured orifice differential pressure.

- Subtract this calculated SRE from that read from the SREI. The remainder is the square root error from the true pulsations sources.

SUMMARY

Pulsations or flow turbulence of certain frequencies in metering runs can cause excitations in the gage lines of the SREI transducer which may cause the SREI to report a spuriously high square root error. The SREI transducer gage lines may be excited at their resonant frequency even though the normally installed gage lines are not excited. Fortunately, this phenomena is rarely encountered in the field. It is difficult to define precisely a minimum measured SRE that would be considered acceptable in all cases and require no further diagnostics. The flow measurement accuracy requirements of the meter are a strong factor in this determination. However, SRE measurements in excess of 0.25 percent indicate, in nearly all cases, the need for further meter diagnostics with a spectrum analyzer to determine the possibility of SREI gage line excitation. As a rule of thumb, pulsation frequencies less than 80 Hz will generally not excite the standard SREI flexible gage lines. If pulsations greater than 80 Hz are present, as determined with a spectrum analyzer connected to the output signal port of the SREI, the possibility of SREI gage line excitation exists which could lead to spurious SRE measurements. In that case, double-z gage lines (Figure 2) should be used to shift the SREI gage line resonant frequencies higher than the normal 100 to 160 Hz range.

With sufficient care, knowledge of the physical processes involved, and awareness of the inherent limitations of the device, the SREI will continue to provide users a valuable diagnostic device for screening metering installations for square root measurement errors.

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