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PULSATION

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newer technologies along with the better understanding of the pulsation phenomena will ultimately reduce the pressure reduction requirements for accurate measurement. This combination will then allow for true efficiency improvements ranging down to individual cylinders within compressors.

Pulsation Effects on Orifices

As the device of preference for the measurement of natural gases there has been a considerable body of independent experimental work conducted upon the orifice determine the effects of pulsating flows. The published literature outstrips that on the effects of pulsation on any other device by orders of magnitude. This documentation unfortunately leads those who are naive about gas flow measurement to point to the problems of orifices relative to other meters rather than realizing that so little is known about others that their problems are essentially unknown.

The term pulsation effect can be considered the general term for a combination of various physical phenomena that result in a pulsation effect. Since these can be described on an individual basis they will be covered in the individual sections.

Square Root Error

The term square root error is actually a misnomer since it is not a true error, but more correctly a misapplication of data. Orifice flow rates like other differential devices are dependent on the measurement of differential pressure. With this differential the flow can be calculated by an equation which resembles

$$Q = C' \sqrt{\Delta P} \tag{1}$$

For a pulsating flow this equation holds for any instant in time. If the flow varies in a manner described by

$$Q = Q_o + q \sin wt \tag{2}$$

then the differential pressure would vary according to

$$\Delta P = \frac{1}{C'} [Q_o{}^2 + 2Qq \sin wt + q^2 \sin^2 wt] \tag{3}$$

Considering both equations (2) and (3) we will now calculate what is necessary to determine the throughput of the meter over a given time. For equation (2) the volume passing through the meter is

$$Vol = Q \times time = Q_o \times time \tag{4}$$

Note that the term q sin wt is not present. This term drops out since it has equal positive and negative components so it averages out to zero. This is shown in Figure 1 and is called time averaging.

If however we were to time average equation (3) we would get a different result. The time average is

$$\overline{\Delta P} = \frac{1}{C'} [Q_o{}^2 + q^2 \sin^2 wt] \tag{5}$$

In this case the second term 2Qq sin wt drops out since it has both equal positive and negative terms. The third term ($q^2 \sin^2 wt$) however, does not drop out since it is always positive. What does this do to our flow rate calculation. If we use the $\bar{\Delta}\bar{P}$ from equation (5) to calculate flow from equation (1) we get

$$Q = \sqrt{Q_o^2 + q^2 \sin^2 wt} \qquad (6)$$

or a volume of

$$Vol = Q \times time = \sqrt{Q_o^2 + q^2 \sin^2 wt} \times time \qquad (7)$$

Note that equation (7) shows a different and incorrect flow from equation (1). The resulting flow calculation starting from equation (3) and averaging the ΔP to that of equation (5) is what is done with a chart recorder. The result is then a possible error depending on the magnitude of q' and the averaging time for pulsating flows. Figure 2 shows this effect.

All of the above are shown schematically to demonstrate the principle. A farther demonstration based on real numbers is shown in the table below for natural gas at 600 psig.

TABLE 1
Square Root of Average vs Average of Square Roots

Flow Condition	Average Flow Rate	"Error" in Volume
Steady Flow	2.54×10^6 SCFH	0%
10% Flow Pulsation (10 H_z) (Average ΔP Equation 6)	2.730×10^6 SCFH	7%
10% Pulsation (10 H_z) (Average of ΔP Equation 3)	2.54×10^6 SCFH	0%

This simple example illustrates an important concept which can be used for

1. The best measurement with orifices or any other type of meter is that for steady flow conditions.

2. None of the above applies in a steady flow situation (see reference 1).

3. If pulsation is suspected tests with a square-root error indicator type device should be made to assist in either determining the level of pulsation (i.e. is it there) and to ascertain whether the "fixes" which may have been made have solved the problem.

4. Over proper ranges the theoretical and experimental work conducted by the Southern Gas Association at Southwest Research Institute indicates that proper data handling can increase the accuracy of measurement under pulsating conditions. Further studies are necessary.

5. When pulsation is detected it is important to consider the "full" measurement system. This includes not only the effects at the tap, but also all lead lines, valving in lead lines, transducers and flow computers.

6. The above results are from multi year independent studies on the orifice. The recommendation to use other meters to solve pulsating situations are based on extremely small data bases which could lead to even more severe errors than were originally encountered.