Ultrasonic Flowmeter Calibration Intervals

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Abstract: Currently no recalibration interval has been recommended by ultrasonic meter manufacturers or required by the AGA in the United States. Ten years ago the natural gas industry in the United States began acquiring ultrasonic flowmeters. A large amount of data has been collected over the past few years detailing how the performance of an ultrasonic flowmeter is affected by use in the field. The data from 35 meters calibrated at CEESI Iowa will be analyzed to investigate the effects of time on the performance of ultrasonic meters.

Keyword: Ultrasonic Flowmeter, Calibration

1. Statement of Objective

The use of ultrasonic meters for custody transfer started to become widespread in early 2000. It is difficult to determine if any or all of these meters should have been recalibrated since their installation. AGA 8 does not address recalibration intervals. Likewise, most sales contracts do not specify recalibration intervals. Regulated industries in some countries adhere to recalibration intervals; in Canada for example, a six year interval is required.

The CEESI Iowa facility began to calibrate meters in March 1999. A small number have been returned to the facility for recalibration. The present paper documents the beginning of a data mining process that will identify meters that have been returned for recalibration and evaluate any change in meter performance. Thirty five ultrasonic flowmeters were identified as having been in field use for at least four months before being returned to the CEESI Iowa facility for recalibration. The line sizes of these meters range between four and twenty four inches. Three activities are typically performed during the calibration of an ultrasonic flowmeter: an initial calibration, calibration factors are entered into the meter registers, and a verification test. Only data from the first activity, the calibration, was used for this study.

Meter conditions can change between calibrations in several ways. Examples include cleaning, new transducers, or new electronics. The changes in conditions of the meters used in this analysis have not yet been determined. It is probable that some or all of the meter components may have been replaced during the interval between calibrations.

2. Meter Deviation

The AGA9 definition of meter "error" is the difference between velocity values reported by the meter and calculated from the laboratory standard. The ISO VIM states:

> "The error concept can be used when there is a single reference quantity value to refer to, which occurs if a calibration is made by means of measurement standard of negligible measurement uncertainty."

Current day ultrasonic meter calibration processes are characterized by meters exhibiting long term random effects that are smaller than the uncertainties of the laboratories. It is suggested that the use of the term "error" does not meet the ISO VIM definition. This paper will use the term "offset" to represent the difference in velocity values.

Multiple datasets were available for each ultrasonic flowmeter. A regression analysis was performed on the meter velocity and meter offset data from the oldest dataset. Subsequent calibration datasets were compared to the results of the regression analysis. The comparison values for each data point are expressed as a percent deviation.

The results of the regression analysis were first used to quantify the scatter of the original calibration data from the curve fit. The results of this comparison serve as baseline short term random effects data. The regression analysis results were also used to quantify the shift in meter performance from the initial calibration.

3. Figures

Five types of plots will show the data on the 35 meters. The figures are:

1. Percent Deviation of all data points as a function of time
2. Percent Deviation of all data points as a function of velocity with performance bands
3. Percent Deviation as a function of velocity for all data taken during initial calibration with performance bands
4. Percent Deviation as a function of velocity for all data taken during specified time lapse with performance bands
5. Performance band values for each year at specific meter velocity values

The plots of percent deviation as a function of velocity are shown with performance bands at 95% intervals. The plot shows that the random variations increase with decreasing velocity which is common for most measuring instruments. This effect is often referred to as "percent of full scale effects".

The statistical interval width is $\pm 2s_c$ where s is a standard deviation expressed in percent. In this case, S_c can be defined by an equation of the form:

$$S_c = (a + b * v^c) * 100\% \qquad \text{[Eq. 1]}$$

where v is velocity. Traditionally the coefficients "a", "b" and "c" are selected until the interval appears to contain 95% of the data, a methodology more qualitative than quantitative. A table of all the coefficients used in the plots is included at the end of the paper (Table 1).

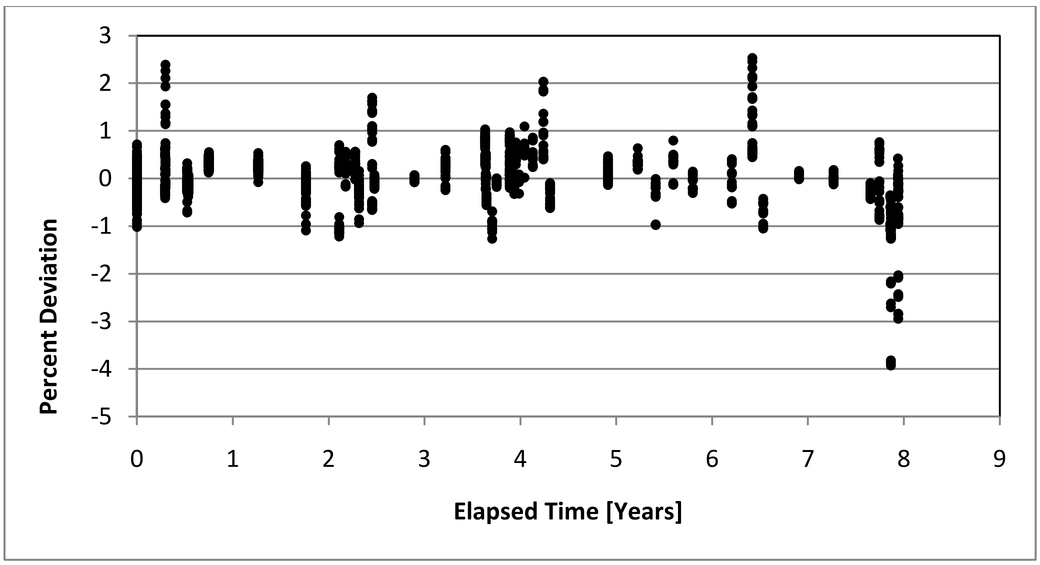

Figure 1. Percent Deviation Values as a function of Elapsed Time

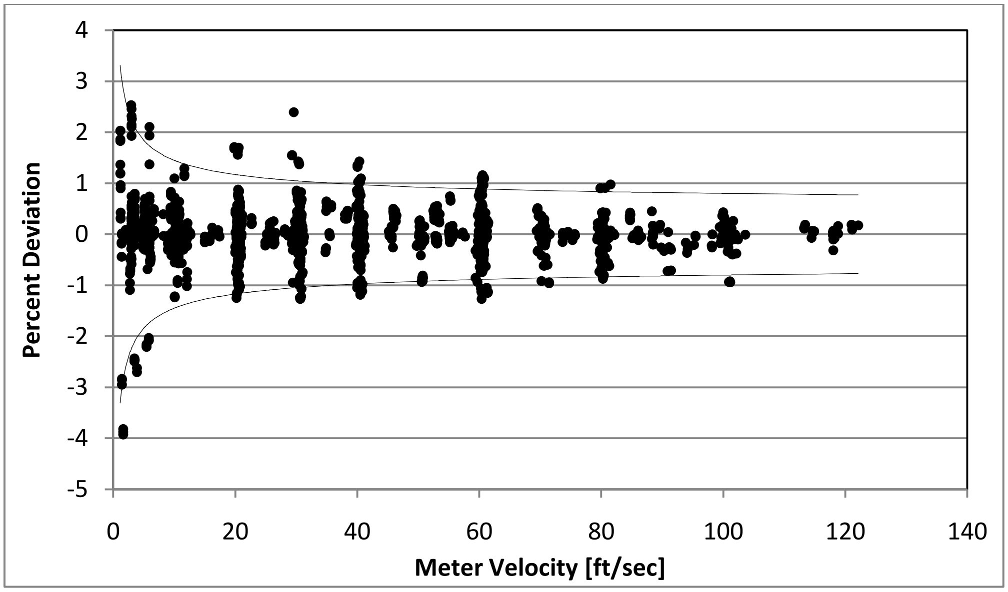

Figure 2. Percent Deviation Values as a function of Meter Velocity with Performance Bands

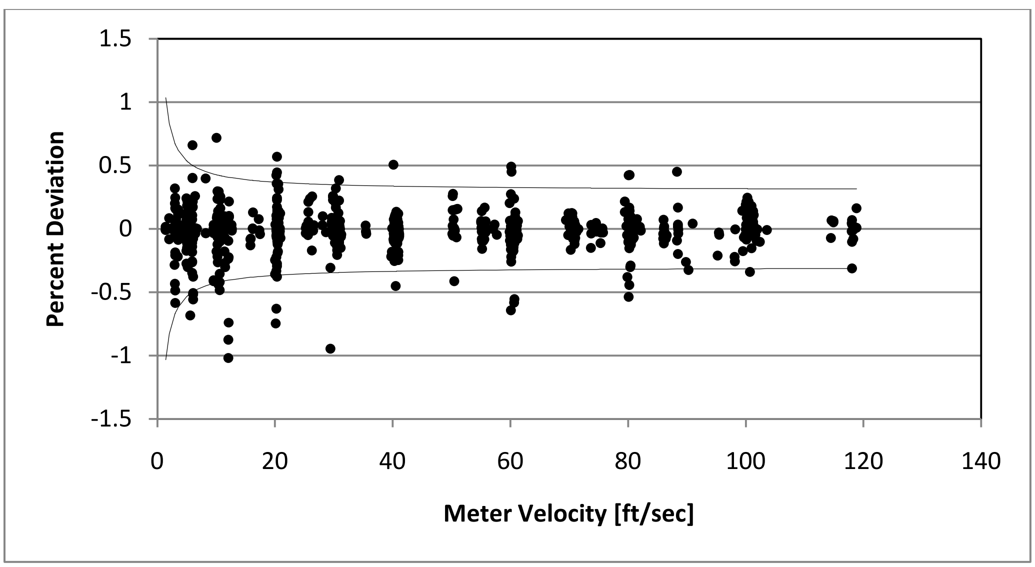

Figure 3. Percent Deviation as a function of velocity for all data taken during initial calibration with performance bands

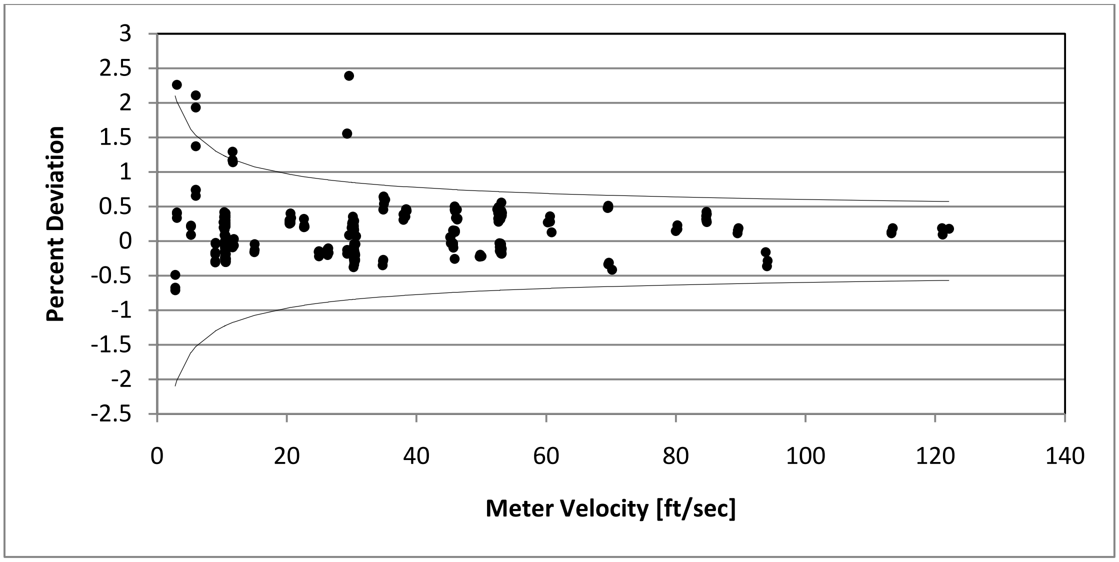

Figure 4. Percent Deviation during 1st year with Performance Bands

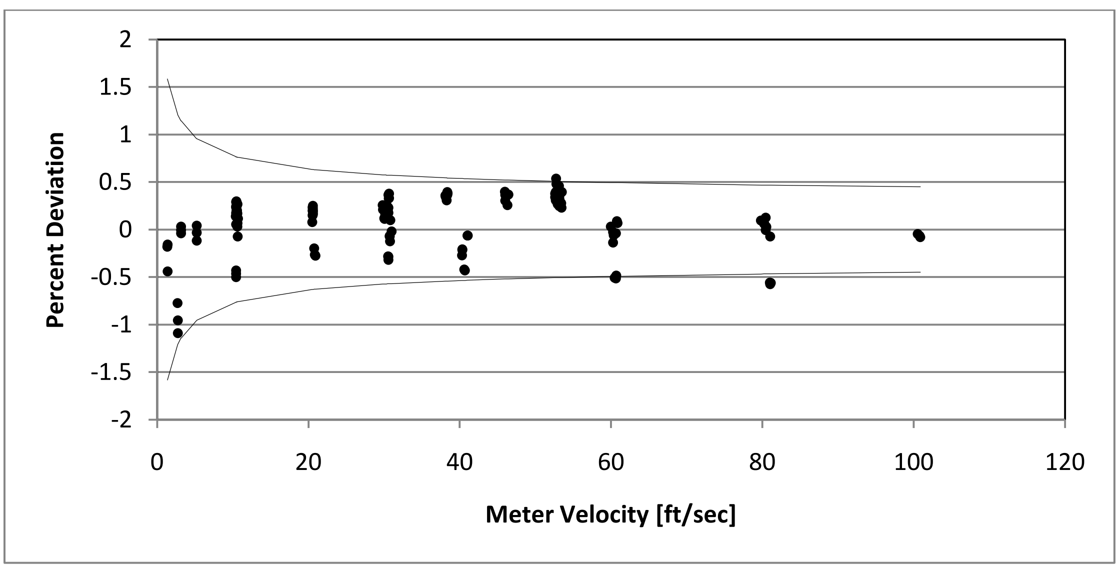

Figure 5. Percent Deviation during 2nd year with Performance Bands

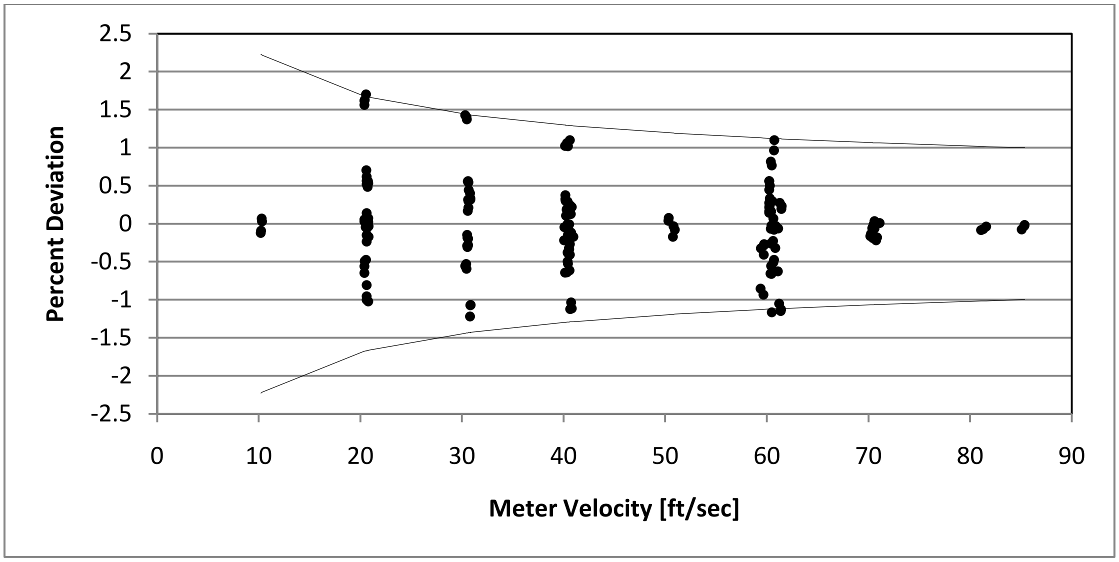

Figure 6. Percent Deviation during 3rd year with Performance Bands

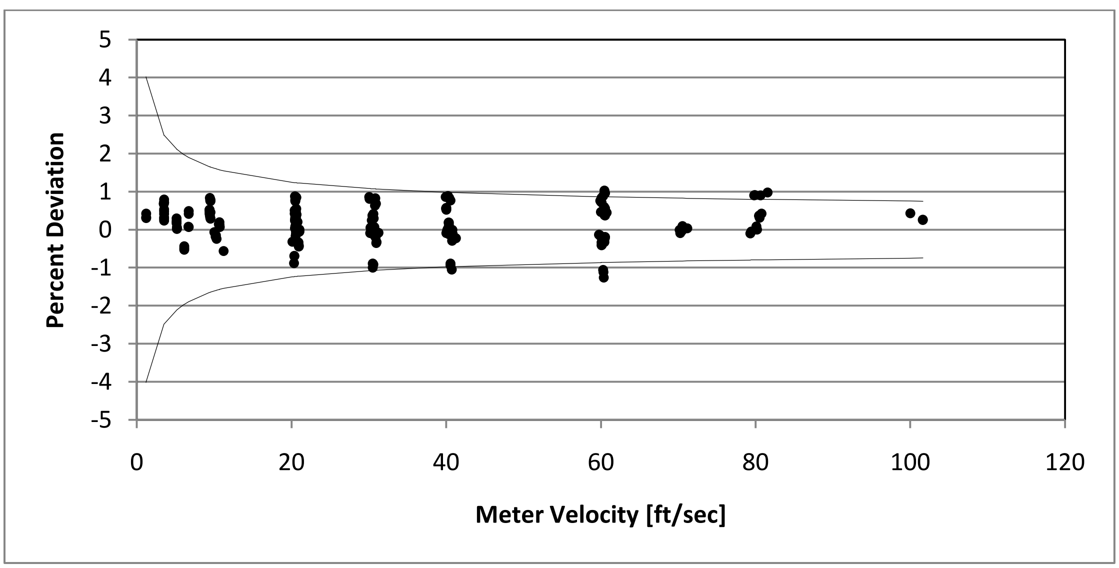

Figure 7. Percent Deviation during 4th year with Performance Bands

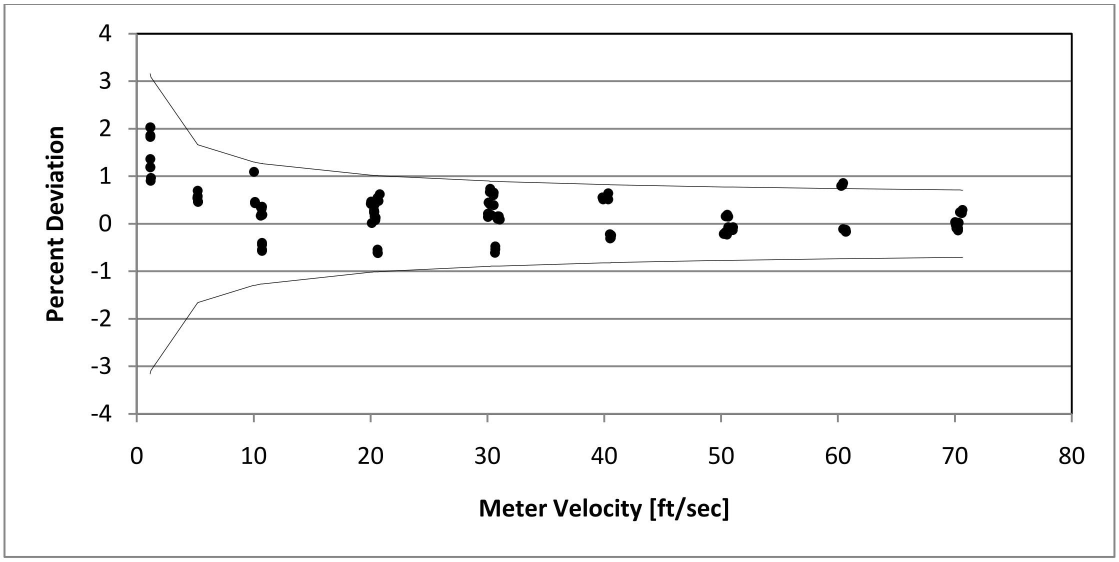

Figure 8. % Dev. during 5th year with performance bands

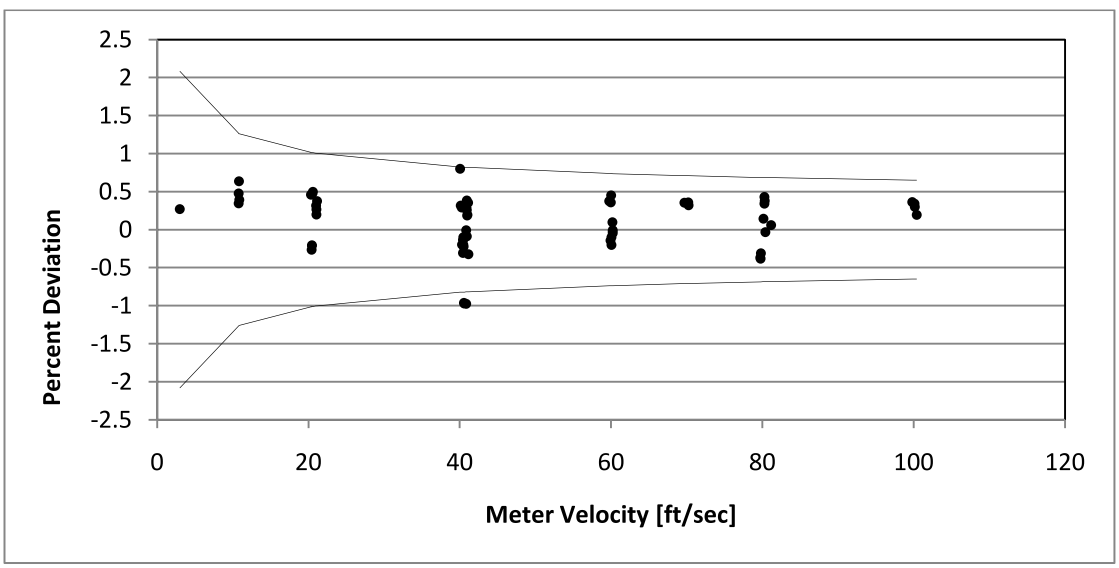

Figure 9. Percent Deviation during 6th year with Performance Bands

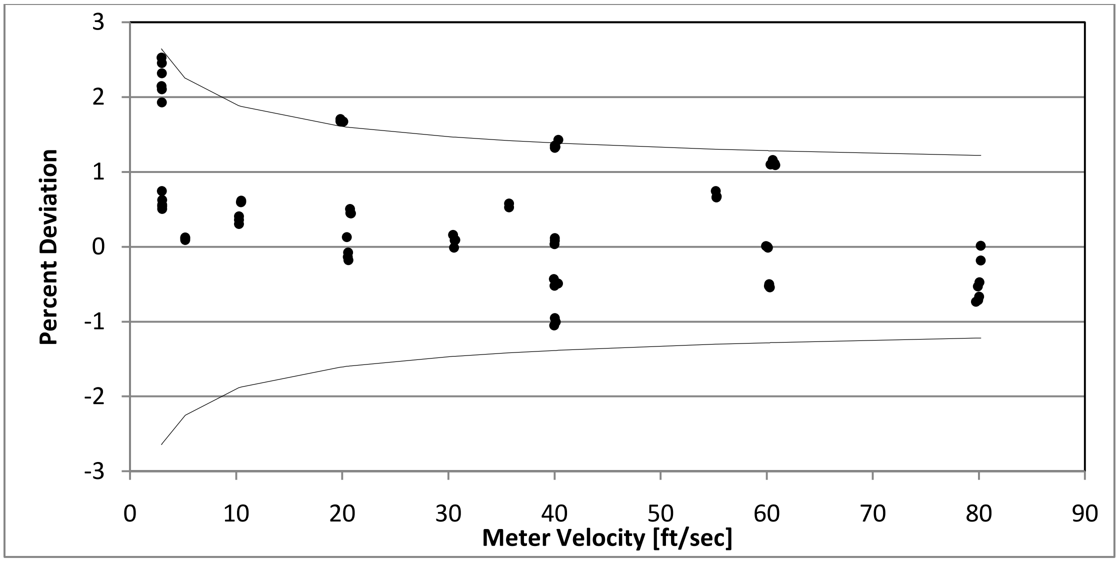

Figure 10. Percent Deviation during 7th year with Performance Bands

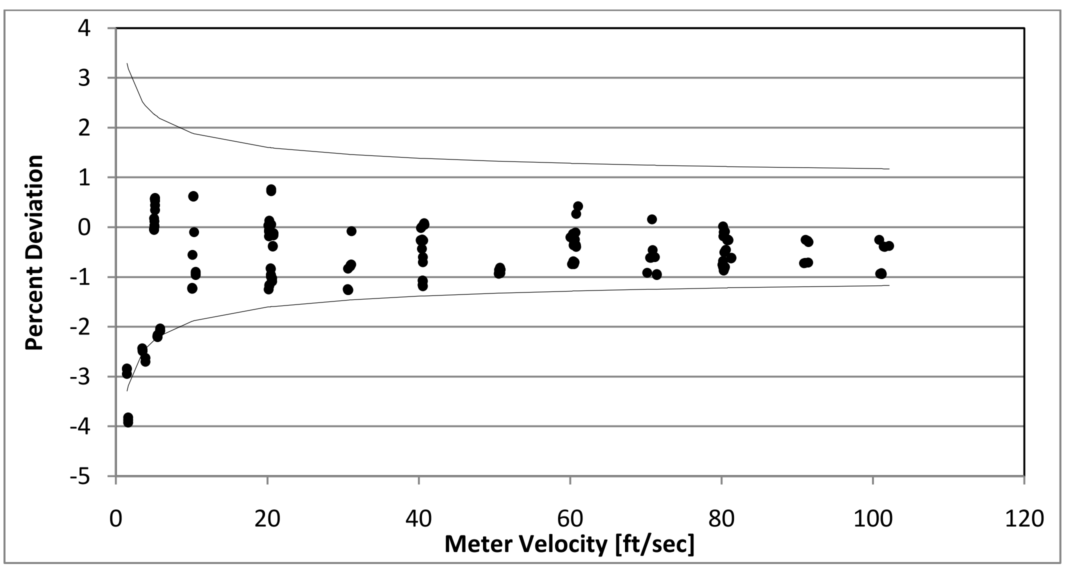

Figure 11. Percent Deviation during 8th year with Performance Bands

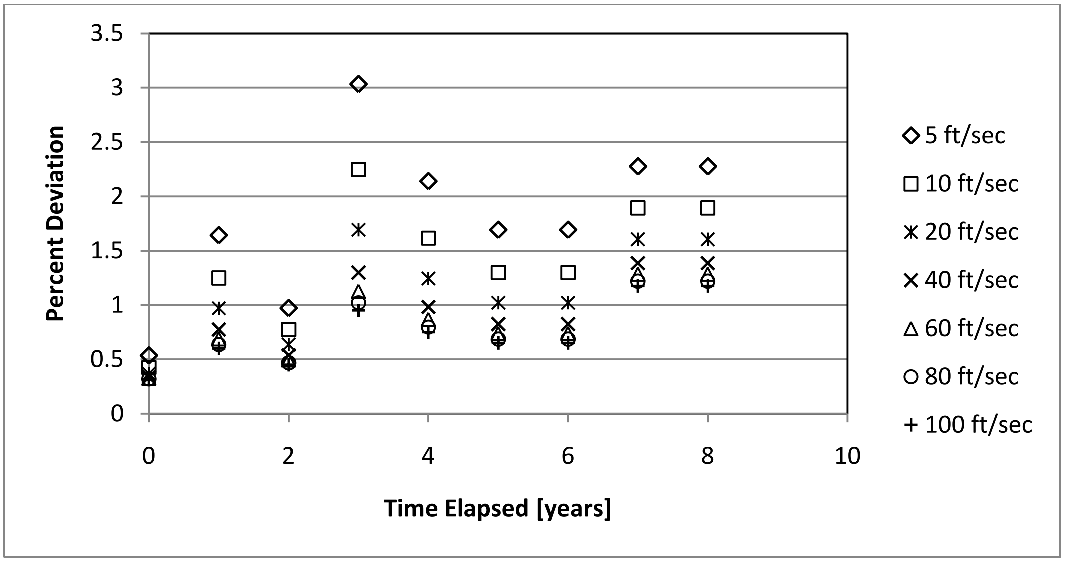

Figure 12. Performance Band Values for each Year at Specific Meter Velocity Values

Table 1. Performance band coefficients

Figure	a	b	c
2	0.5	3	-0.5
3	0.3	1	-0.9
4	0.3	3	-0.5
5	0.3	1.5	-0.5
6	0.35	6	-0.5
7	0.35	4	-0.5
8	0.35	3	-0.5
9	0.35	3	-0.5
10	0.7	3	-0.4
11	0.7	3	-0.4

4. **Discussion and Summary**

Figures 1 and 2 represent two initial plots of the data. The figures show the dependency of meter offset on velocity and time but do not allow the effects to be separated. The concept of a confidence interval is illustrated in Figures 2 and 3. In both cases 95% of the data lie between the performance bands. Figures 2 and 3 seem to indicate that all ultrasonic flowmeters have similar performance as a function of velocity.

Figures 4 thru 11 represent an attempt to separate the effects of time and velocity which could not be done in Figures 1 and 2. Table 1 lists the coefficients used to calculate the performance bands in each of Figures 2 thru 11. The performance bands seem to vary from year to year without any clear trend. It should be remembered that the meters from one year to the next are completely different; the position of the bands may be dominated by one or two meters. It is hoped that this is a large enough sample to represent the behavior of the installed base of ultrasonic flowmeters. It is observed that while the performance bands are symmetrical the data are not evenly distributed within the bands. For example in Figure 8 the deviations are mostly positive while in Figure 11 the deviations are mostly negative. This lack of symmetry might indicate the sample size for any one year may not provide for valid statistical analysis.

Figure 12 uses the analysis from Figure 4 thru 11 to predict a trend in ultrasonic flowmeter performance. The performance band coefficients in Table 1 were used to calculate band values at different velocities. Two observations are clear. First, deviation increases over time for all velocities. Second, the deviation increases as the velocity decreases. Year to year trend variations evident in Figure 12 are likely a result of the limited observations in any one year. Additional analyses incorporating all eight years of data are expected to produce more statistically rigorous conclusions.

Clear qualitative results have been obtained that would indicate changes in ultrasonic flowmeter performance with time. The next step of the analysis is to move towards quantification of the change and provide guidance in the selection of ultrasonic flowmeter recalibration time intervals. It is anticipated that additional meters will be returned for recalibration, these calibration results will be added to the database. Finally, the process to identify meter changes (transducers, electronics, etc) and incorporate them into the database has begun.