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IMPROVED PERFORMANCE FOR LEAK DETECTION SYSTEMS THROUGH STATISTICAL DATA AVERAGING

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NOISE REDUCTION THROUGH AVERAGING

The result of any measurement incorporates, in some combination, not just the true or "actual" state of the object being measured but also random noise from various sources. The object might be a tank or pipeline, for example, and its actual state would be either leaking or non-leaking. Thus, what we are measuring is a particular *aspect* of the object—in this case its rate of leakage. If the noise component of such a measurement meets a specific set of criteria, one can expect to achieve increased accuracy through the averaging of multiple measurements. The criteria that must be met are described below.

THE NOISE MUST BE NORMALLY DISTRIBUTED (GAUSSIAN), WITH A MEAN OF ZERO

The first requirement—that the noise must be normally distributed (Gaussian), with a mean of zero—is fairly straightforward. If one averages a set of values M_i where each value is made up of the actual state of the object measured A, and a Gaussian random noise component N_i ($M_i = A + N_i$), the result is

$$M_{ave} = (A + N_i)_{ave} = A_{ave} + N_{ave}.$$

It is assumed that the actual state is unchanging over the measurement period; thus $A_{ave} = A$, and $M_{ave} = A + N_{ave}$. If the average value of the noise is zero, the value of N_{ave} decreases to zero as the number of measurements approaches infinity. At that point the average measured value is, in principle, identical to the actual state of the object. In practice, of course, one cannot take an infinite number of measurements, and so M_{ave} never reaches A; nevertheless, the noise component does become smaller and smaller as more measurements are averaged. If, on the other hand, the noise had a mean value *not* equal to zero, M_{ave} would approach not A but rather A+N (where N is the mean value of the noise).

THE MEASUREMENTS MUST BE INDEPENDENT

The second requirement is that each measurement averaged must be independent of the previous measurement. When measurements are correlated—i.e., not independent—any systematic errors that were present in the first measurement also occur in the second; errors present in the second measurement occur in the third; and so on. Noise that results from systematic errors cannot be reduced through averaging. For systems that use empirical calibration constants (constants derived from an initial set of tests on a tank or pipeline), the accuracy of the measurement is largely determined by the accuracy of the calibration constant. The error in the calibration constant shows up identically in all test measurements (hence each measurement is correlated through the calibration constant) and its effect is not reduced when multiple tests are averaged. If, on the other hand, each measurement is uncorrelated with the previous one, the errors in a set of measurements will be truly random (some high, some low, some positive, some negative, etc.) and their average will reduce to zero as the number of measurements is increased.

THE SIGNAL AND NOISE MUST BE INDEPENDENT

Thirdly, the signal and noise must be independent. This means that the noise at the time of the measurement must not have an effect on the actual state of the object. In leak detection, where the aspect of the object that is being measured is the rate of leakage, the implication is that the rate of leakage must not be affected by the noise. Whether leakage is determined by measuring volume or pressure, the predominant source of noise in a pipeline is temperature.

In a pressure test, if the temperature of the fuel is dropping, the pressure in the line will decrease. If the pressure in the line is decreasing, the leak rate is also decreasing (because there is less pressure to force the liquid through the hole). Conversely, if the temperature is increasing, the pressure in the line will increase, and so will the leak rate. Clearly, the noise in this case has a direct effect on the aspect being measured (i.e., the leak rate). The noise has the effect of modifying the statistical distribution of the measurement in such a way as to decrease the effectiveness of averaging multiple measurements.

In the case of a volumetric measurement system, however, the pressure is held constant while the volume changes are measured directly. In volumetric tests, increases and decreases in the volume of fuel that are caused by the changing temperature do not affect the line pressure, and therefore do not affect the leak rate. Such a system can make maximum use of a scheme that averages multiple measurements.

CONCLUSION

In leak detection, statistical data averaging can be a valuable tool in noise reduction and, consequently, in decreasing the detectable leak rate, increasing the probability of detection and decreasing the probability of false alarm. Substantial improvements in system performance can be realized if multiple tests are averaged. In practice, Vista leak detection systems have demonstrated that their performance can be improved by a factor of five or more through the use of this method. The averaging method, however, cannot be applied to all technologies, and unless certain precautions are taken, this strategy can be error-prone. The key to accurate results is to ensure that the noise has a mean of zero; that each measurement is independent of the others; and that the signal and noise are independent of one another.