

Leak Detection Using Conductivity

BACKGROUND

Virtually all industries from food and beverage to chemical processing use heat exchangers, condensers, or jacketed vessels. Leakage of the process into the cooling water represents a loss of product and can be a source of fouling or corrosion in the cooling water system.

Conversely, leakage of the cooling water into the process can be a source of contamination. An example is the leakage of cooling water into steam condensate, which is a source of contamination in the steam-water circuit.

BASIC PRINCIPLE

The basic principle behind leak detection using conductivity is measuring and alarming the change in conductivity in a sample brought about by a leak into it by a contaminant. The contaminant either increases or decreases the conductivity of the sample depending upon its solubility with the process solution.

How well conductivity can detect leaks is determined first of all by the difference in conductivity between the sample and the contaminant. The greater the conductivity difference, the more sensitive leak detection will be. For any reasonable leak detection sensitivity, the conductivity of the contaminant should be at least 100 times greater than the sample conductivity.

Where a specification exists for the maximum allowable conductivity of the sample, sensitivity of leak detection is not an issue and a conductivity measurement is all that is required. However, even in these instances, using two conductivity measurements can often isolate and identify the leak source.

LEAK DETECTION WITH A SINGLE ANALYZER OR TWO ANALYZERS (DIFFERENTIAL CONDUCTIVITY).

The second determining factor in how effective conductivity will be in leak detection is how much the sample conductivity must increase to reliably indicate the presence of a leak. The smaller the

increase that is necessary, the better the sensitivity will be.

How large a conductivity change is needed is determined by 1) the conductivity range of the uncontaminated sample; 2) how fast the sample conductivity changes; and 3) the transit time, which tells how long the sample takes to pass through the potential leak source.

The above considerations also determine whether there is an advantage in using differential conductivity over using a single analyzer.

LEAK DETECTION WITH A SINGLE ANALYZER

The conductivity of an uncontaminated sample normally varies between a high and low extreme. The worst case for leak detection with a single analyzer is when the sample conductivity is at its minimum. A leak can be present, which increases the conductivity up to the normal sample maximum conductivity. Since conductivity is not above a normal, expected value, the leak is not detected.

Given this fact and the dependence of sensitivity on the ratio of the sample conductivity to the contaminant conductivity, the overall sensitivity (S_s) with a single analyzer can be estimated from the following:

Equation (1)

$$S_s = \frac{K_H - K_L}{K_C}$$

where S_s is the sensitivity in volume of contaminant per volume of sample; K_H and K_L are the maximum and minimum normal sample conductivity; and K_C is the contaminant conductivity.

Sensitivity with a single analyzer is limited by the normal variations in sample conductivity.

Alarming for leak detection should be set at approximately 5% full scale above the maximum normal conductivity or other reliably measurable conductivity increase.

DIFFERENTIAL CONDUCTIVITY

Using two conductivity analyzers, one before and the second after the possible leak source, can cancel out the normal changes in sample conductivity by looking at the difference in the two measurements. Ideally, any conductivity difference should be due to a leak, which is usually a relatively small change, resulting in good sensitivity.

In the real world, how fast changes occur in the normal sample's conductivity, how fast the transit time of the sample is, and as well as how normal errors of measurement can occur, will decrease the sensitivity of differential conductivity.

BEST CASE FOR DIFFERENTIAL CONDUCTIVITY:

When the normal conductivity change in the sample is much slower than the transit time, both analyzers in a differential conductivity measurement are seeing essentially the same sample, and variations in the sample conductivity are effectively cancelled out.

But measurement errors in both analyzers will cause the differential conductivity to vary above and below zero, by 2 times the error in each measurement. The sensitivity can be estimated from the following formula, based on the worst case conditions:

Equation (2)

$$S_D = \frac{4e}{K_L} \times \frac{K_H}{K_C}$$

where S_D is the sensitivity in volume contaminant per volume sample; e is the estimated measurement error in conductivity units ($\mu\text{S/cm}$ or mS/cm); K_L , K_H , and K_C are the minimum and maximum sample conductivities and contaminant conductivity respectively.

Since, even in the worst-case scenario, the error in measurement is much smaller than the conductivity variations, this sensitivity is considerably better than with a single analyzer.

SAMPLE CONDUCTIVITY CHANGES FASTER THAN TRANSIT TIME:

When the sample conductivity change is faster than the transit time through the leak source, the differential conductivity without any leak can be significantly positive or negative. In the extreme case, where the sample conductivity can change from its normal maximum to minimum in a period of time shorter than the transit time, a leak, which would be detected using a single analyzer on the outlet, could go undetected using differential conductivity. A single analyzer after the potential leak source is the best choice in these cases.

RULES FOR APPLYING CONDUCTIVITY TO LEAK DETECTION

- 1) The contaminant conductivity should be at least 100 times the sample conductivity.
- 2) If there is a specified maximum sample conductivity use that value for alarming.
- 3) With a single analyzer on the outlet of a potential leak source, the sensitivity of the leak detection in volume fraction can be estimated by equation (1).
- 4) Differential conductivity can increase the sensitivity of leak detection only if the rate of the normal sample conductivity change is slow compared to the sample transit time through the leak source. The sensitivity can be estimated from equation (2).
- 5) If the rate of the normal sample conductivity change is fast relative to the transit time, leak detection with a single analyzer is more sensitive than differential conductivity.
- 6) To evaluate a potential leak detection application you need to know:
 - a) sample conductivity range
 - b) contaminant conductivity
 - c) How fast the sample conductivity can change relative to the transit time through the leak source.

ADDITIONAL CONSIDERATIONS

- 1) Accurate temperature compensation is important. There can be significant temperature fluctuations, and, in the case of differential measurements, a temperature difference between the two measurement points. Inaccurate temperature compensation can give false indications of leaks or mask real leaks.
- 2) If the sample and the contaminant are both concentrated solutions, the potential for them reacting upon mixing or the conductivity of the mixture not being additive should be considered. The best course of action is to titrate the sample with the contaminant and measure the conductivity response. The conductivity change at a particular volume to volume ratio of contaminant and to sample can be used to estimate sensitivity.
- 3) Choice of Conductivity measurement technique: The choice between using a contacting or toroidal conductivity is based on the usual considerations of conductivity range and potential for fouling or corrosion in the sample.

INSTRUMENTATION

Model 1056 Analyzer

- MULTI-PARAMETER INSTRUMENT – single or dual input. Any combination of pH/ORP/ISE, Resistivity/Conductivity, Chlorine, Oxygen, Ozone, Turbidity, Flow.
- LARGE DISPLAY – easy-to-read process measurements.
- SEVEN LANGUAGES: English, French, German, Italian, Spanish, Portuguese, and Chinese.
- HART AND PROFIBUS DP Digital Communications.



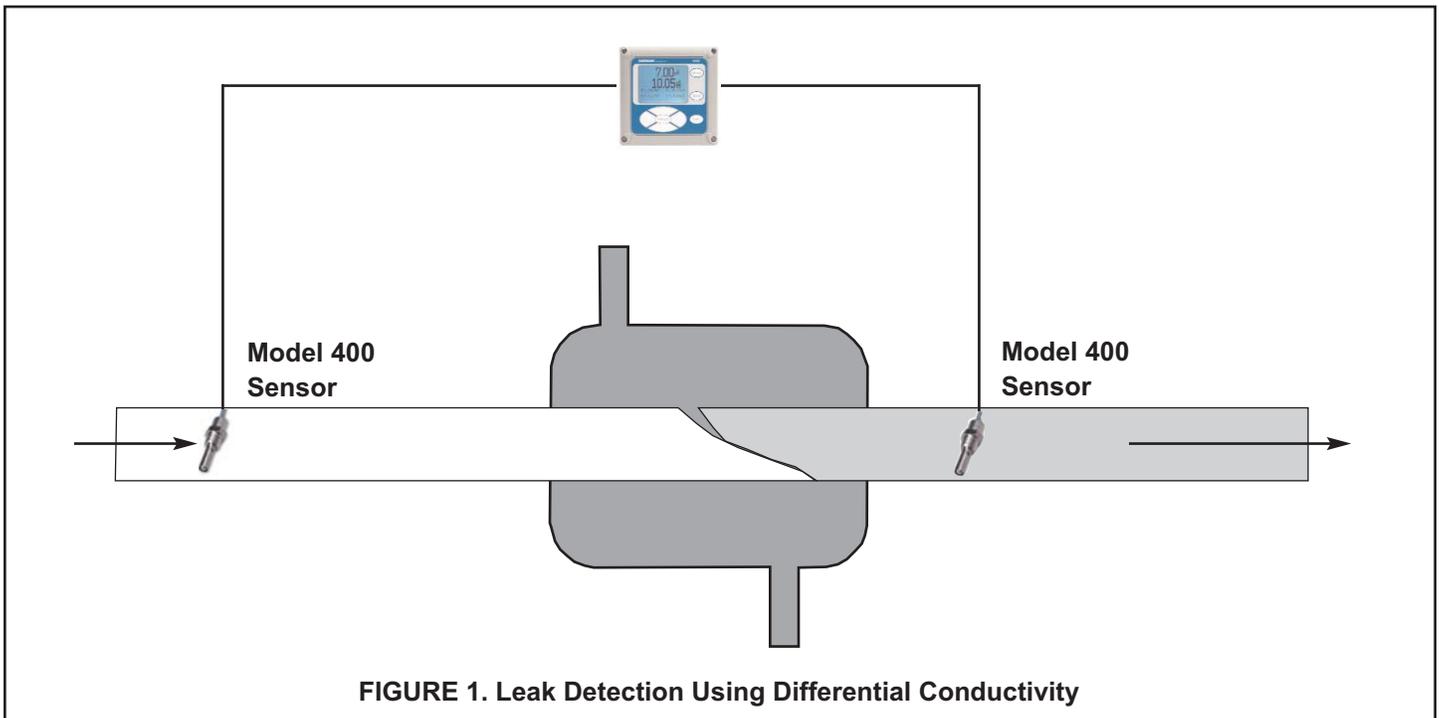
Model 400 Series Conductivity Sensors

- Ideal for use in low conductivity (100 $\mu\text{S}/\text{cm}$) and clean processes
- Titanium palladium electrodes have exceptional chemical resistance and provide consistent, reliable measurement.
- 3/4 in. NPT 316 SS process connection for long lasting service.
- Pt 1000 RTD for accurate temperature compensation.



Model 226 Toroidal Conductivity Sensor

- Ideal for use in high conductivity and coating processes.
- Available in chemically-resistant PEEK.
- Pt 100 RTD for accurate temperature compensation.



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