The Quadbeam™ Alternating Light Principle for Suspended Solids Measurement

The purpose of the Quadbeam™ Alternating Light Principle design is to improve the measurement reliability of optical suspended solids and turbidity instruments. Sensors that use the Quadbeam™ technology compensate for most sources of measurement error, providing unrivalled accuracy and reliability when compared with competitive systems.

The most basic method of suspended solids measurement is obtained by shining a light of known intensity a fixed distance through a medium to a photocell detector. Suspended solids in the medium attenuate some of the light. The detector receives light not absorbed by the solids. The quantity of light received gives a measure of the attenuation by the medium which corresponds to suspended solids concentration or turbidity measurement.

The optical method of suspended solids measurement depends on several variables, including light source intensity and detector sensitivity. Variations in these parameters will introduce errors.

The main causes of light source variations are:
- Dirt accumulation.
- Ageing of the light sources.
- Voltage variations at the light source.

- The main causes of detector variation:
- Dirt accumulation.
- Ageing of the detectors.

The Quadbeam™ principle of light attenuation eliminates almost all variations when measuring suspended solids.

The 90 degree light scattering principle (ISO27027) is the preferred method for low range turbidity measurements. However, most of these instruments use a single beam design. Single beam instruments rely on mechanical cleaners to eliminate variations due to dirt accumulation, but do not compensate for aging or voltage variations.

The alternating light principle of suspended solids measurement has been known for many years and we make no claim to its originality. However we have made major improvements to both its performance and reliability.

Series 20 Immersion Style Suspended Solids Sensor

Series 20 Hygienic Style Suspended Solids Sensor specially manufactured for the food and dairy industry

The Alternating Light Principle Explained

One Light-One Detector

The simplest method of optical suspended solids measurement is shown in Figure 1. Light (E) strikes a photocell detector (D) that generates an electrical current (I). The detector output current (I) is a function of the intensity of the light source (E), the detector characteristics (D), the distance between the light source and the detector (X) and absorption by the medium ( ).

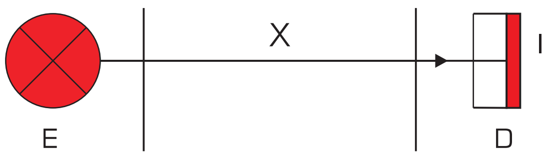

Fig 1: One light and one detector

Although the distance between the light source and detector is fixed, uncontrollable variations in both light intensity and detector sensitivity will still be sources of error. There is no compensation for reduced system performance due to component ageing or contamination. For example, if the light intensity is reduced by accumulated dirt on the light source window, the smaller signal received by the detector will be interpreted by the system as an increase in suspended solids concentration.

One Light-Two Detectors

Measurement accuracy of a one light, one detector system can be improved by adding a second detector at a greater distance (X_2) from the light source Fig 2.

Since physical law dictates that light intensity decreases as a function of distance, the output of the more distant detector (D_2) will always be lower than the output of the closer detector (D_1) because it will receive less light.

The output of both detectors expressed as a ratio, Ix_1/Ix_2, is a measurement value that depends on absorption by the medium but does not depend on light source intensity.

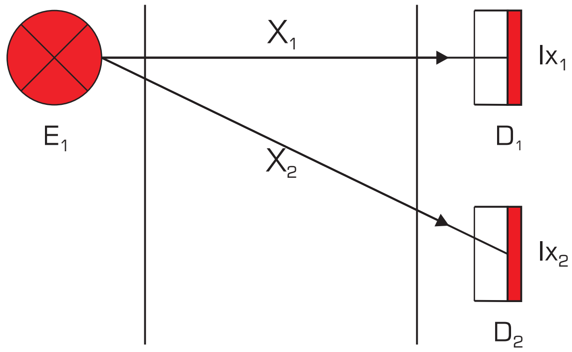

Fig 2: One light and two detectors

$$Ix_1 = 80\mu A$$
$$Ix_2 = 40\mu A$$

$$\frac{Ix_1}{Ix2} = \frac{80\mu A}{40\mu A} = 2$$

The ratio increases with an increase in absorption. Distance is not a variable because both distance values are fixed. This method compensates for light variation. The ratio remains constant if light reaching each detector is also reduced by 25%.

$$Ix_1 = 60\mu A$$
$$Ix_2 = 30\mu A$$

$$\frac{Ix_1}{Ix2} = \frac{60\mu A}{30\mu A} = 2$$

However, a dirty or ageing detector in the system could produce inaccurate measurement because it would affect the output of only one detector. This variable would be interpreted by the system as a change in suspended solids concentration.

Two Lights-One Detector

Measurement Accuracy of the one light - one detector system can also be improved by using one detector with two light sources, switched on and off alternately, (Fig 3). The detector signals, expressed as a ratio Ix_1/Ix_2 provides a measurement value that depends on absorption by the medium but does not depend upon detector sensitivity.

$$Ix_1 = 80\mu A$$
$$Ix_2 = 40\mu A$$

$$\frac{Ix_1}{Ix2} = \frac{80\mu A}{40\mu A} = 2$$

Again, the ratio increases with an increase in absorption. Distance is not a variable because both distances are fixed.

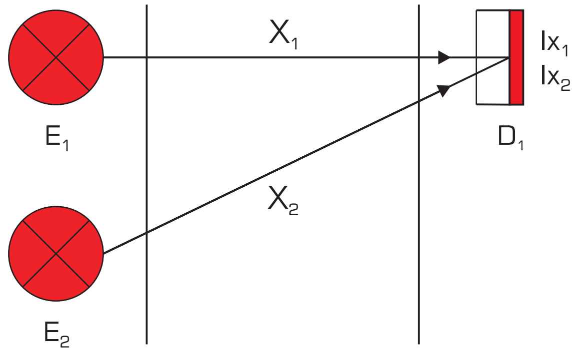

Fig 3: Two lights and one detector

This method compensates for changes in detector sensitivity. Any reduction in detector sensitivity lowers the input from each light source by the same factor and results in a constant ratio. However, light intensity variation caused by dirt accumulation, ageing of the light source or a fluctuation in voltage would produce inaccurate measurement because it would reduce the intensity of the one light source.

Two Lights-Two Detectors

The Quadbeam Alternating light principle compensates for variations in both light intensity and detector sensitivity. It features two light sources (LED's) which are switched on and off alternately and two detector, (Fig 4).

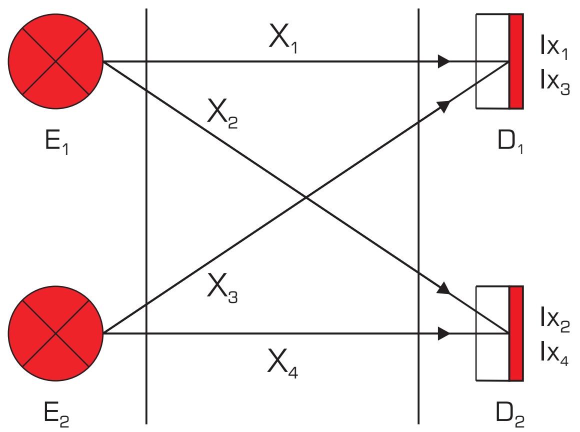

Fig 4 Two lights and two detectors- Quadbeam™ Alternating Light Principle

When E1is turned 'ON' light is transmitted through the process media and each photodetector (D_1 and D_2) receives the light via paths X_1 and X_2 respectively. D_1 and D_2 generate signals based on the amplitude of light each photodetector receives. A ratio (Ra) is created by comparing these results.

$$Ra = \frac{Ix_1}{Ix_2} = \frac{80\mu A}{40\mu A} = 2$$

Because any change in the characteristics of E1 (due to age or contamination) will, affect D1 and D2 equally, this ratio will remain constant . For example, if the light output of E1 is reduced by 25 %, the signals generated by D1and D2 will both be reduced accordingly, but the ratio will remain the same. This eliminates the effects of contamination on E1.

$$Ra = \frac{Ix_1}{Ix_2} = \frac{60\mu A}{30\mu A} = 2$$

The same procedure is performed using E_2, across paths X3 and X4 and a similar ratio (Rb) is created. This eliminates the effects of contamination on E_2.

$$Rb = \frac{Ix_3}{Ix_4} = \frac{30\mu A}{60\mu A} = 0.5$$

To eliminate the effects of contamination or component aging on the detectors, a ratio comparing Ra and Rb is made.

$$\frac{Ra}{Rb} = \frac{2}{0.5} = 4$$

Because a change in the sensitivity of D_1 or D_2 (due to age or contamination) will reduce the light received from E_1 and E_2 equally, this ratio remains constant even if the characteristics of D_1 or D_2 change. For example if dirt covers 25 % of D_1, light received from both E_1 and E_2 will be reduced by 25 % but the ratio will remain the same.

$$Ra = \frac{Ix_1}{Ix_2} = \frac{60\mu A}{40\mu A} = 1.5$$

$$Rb = \frac{Ix_3}{Ix_4} = \frac{22.5\mu A}{60\mu A} = 0.375$$

$$\frac{Ra}{Rb} = \frac{1.5}{0.375} = 4$$

By using these ratios, rather than the direct output from D_1 and D_2, the effects of contamination and component aging are eliminated.

Ambient light is detected by D_1 and D_2 while E_1 and E_2 are off. The resulting "offset" signal is used to correct the measurement. All signals are linearised and combined to produce a reliable 0/4-20mA output signal which is proportional to solids concentration.

By using single wavelength diodes [880 nm] which are outside the visible light spectrum Quadbeam sensors are also insensitive to colour.

Quadbeam Technologies designs sensors of different sensitivity and measuring range by changing the distances between the sensor's light sources and detectors. When they are far apart, the sensor is more sensitive to suspended solids because the longer optical path lengths increase the sensors ability to detect small changes in suspended solids concentration.

However, because an increase in distance reduces the amount of detected light intensity, optical path length also determines the measuring range. For example, in two sensors with identical light sources, the sensor with longer path lengths will detect less light therefore it reaches the upper limit of its measuring range at a lower concentration and has a smaller measuring range. The sensor with shorter path lengths can measure higher concentrations and has a larger measuring range.

"T"Series Sensors

Quadbeam Turbidity Sensors conform to ISO 27027 as they are true nephelometers which measure light at 90 degrees to the transmitted light.

The basic philosophy of the Quadbeam suspended solids sensors have been incorporated in to the T30 sensor in that it uses the detector ratios to eliminate the effects of aging and contamination providing superior span stability.

The measurement is performed using alternating light. Emitter 1 (an LED) is turned "ON" and emitter 2 is turned "OFF". D1 receives the direct path signal of E1 while D2 receives the 90 degree scattered path signal, (Fig 5). Both of these values are stored in memory. Then both emitters (E1and E2) are turned "OFF" and the output of the detectors is again measured and this value is used to compensate the measurement for ambient light.

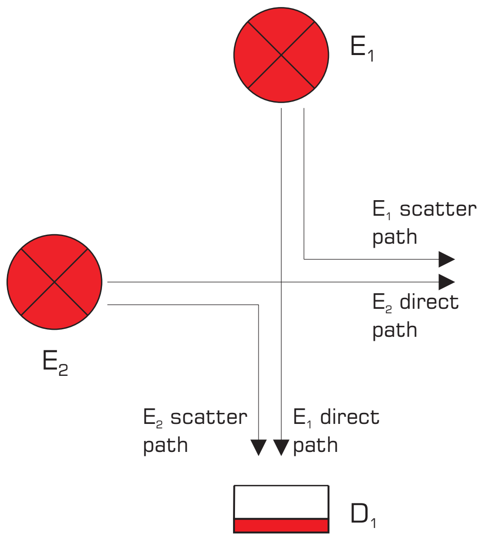

Fig 5: Turbidity sensor direct and scattered light principle

Then emitter 2 is now turned "ON" and the receiver diodes now change roles as D2 now measures the direct path and D1 the 90 degree scatter path. The measurements obtained from detectors D1 and D2 are again placed into memory. As before, when both emitters are "OFF" a measurement of the detector currents are taken for ambient light compensation. For each complete cycle a total of 8 measurements are stored in the sensor's microprocessor.. Digital communication is used between the microprocessor in the sensor and the MSSD53 Transmitter.

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