DESCRIPTION OF THE INVENTIVE SYSTEMS OIL CONTENT MONITORS & ALARMS

The following discussion is about what we believe to be the most reliable instruments available for accurately measuring the amount of free and emulsified oil in water, despite the presence of solids and corrosive elements; the Inventive Systems Oil Content Monitors and Alarms. There are three parts to this discussion: the environment we are working in; the principles of the device; and the application details.

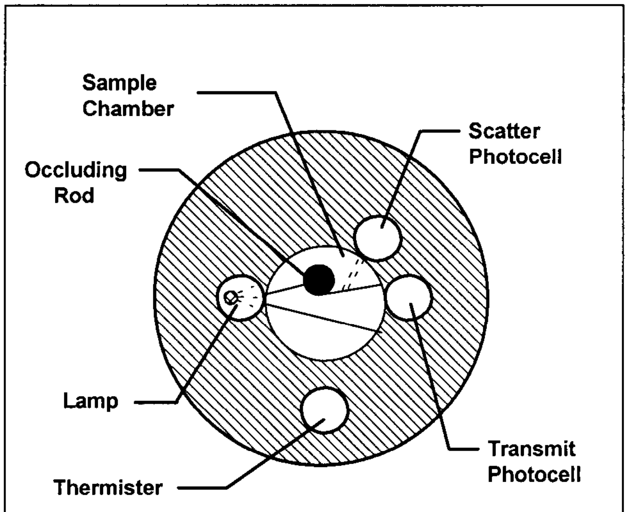
First, a few words about the environment. There are principally two forms of oil that may be found in the water: free oil and emulsified oil. Free oil is in droplets more than 20 microns in diameter. These are so large that they will eventually rise and separate from the water, as cream rises from milk. Emulsified oil consists of droplets less than 20 microns in diameter that are in suspension and will stay that way virtually indefinitely. Our Monitors and Alarms measure both free oil and emulsified oil.

The applications of the Monitors and Alarms are both marine and land-based. The marine application is one of measuring the oil present in the water discharged from the segregated ballast or bilge of a ship. Land-based operations include measuring the amount of oil in the condensate return line of a boiler or the amount of oil in a "process" stream. A good example is a mayonnaise plant where mayonnaise is ubiquitous. No matter how cleanly such an operation is run, vegetable oil is likely to slip into the water lines, which must be monitored to prevent poor heat transfer due to oil coating the walls. A land-based application would be potable watër which has to be monitored before introduction into the distribution system.

Let's now discuss the principles of operation. Imagine for now a pipe with oily water flowing in it. We drill a hole 2 inches in diameter and stick a sensor probe into the water stream. A movable part inside the probe goes in and out. On the retraction part of the cycle we create a vacuum, sucking some water into a chamber and measure that water sample optically. We push it out, and the sample is carried away. This reciprocating motion completes a cycle every 8 1/2 seconds, so we get a reading of the oil content every 8 1/2 seconds.

A cross section of this probe body is depicted below:

A light shines from the Light Source to the other side of the chamber. The Light Source is a small one watt lamp which is detected at a Transmit Photocell and a Scatter Photocell. Now it is important to understand this diagram because it is the heart of the entire device. When the water is pure, the light received at the Transmit Photocell will be what left the Light Source because water is a good transmitter of light. It does not

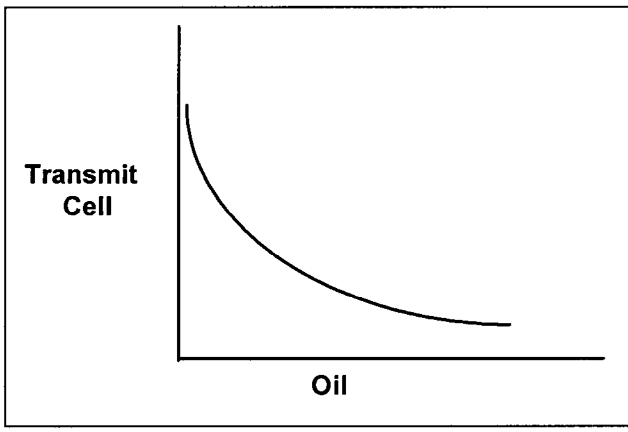


Probe Cross Section

attenuate the light.

As the amount of oil is increased, the light received at The Transmit Photocell will be reduced as the oil absorbs some of the light. The curve that shows this drop off of the light is depicted above.

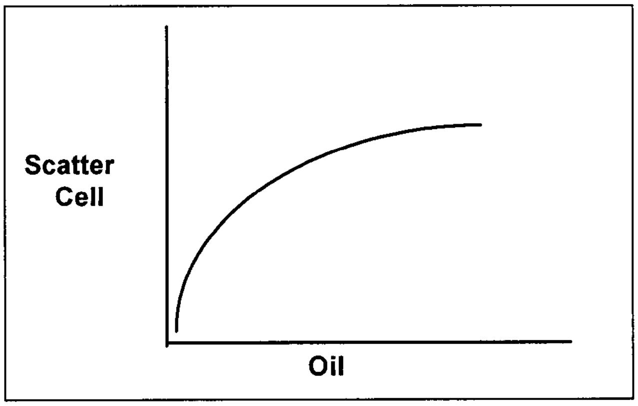
This curve can be distorted by the presence of solids



and by aging of the lamp.
We also have in the chamber a rod which blocks or "occludes" the light to the Scatter Photocell. The light from the Light Source cannot reach this Scatter Cell directly. Oil droplets act as prisms, refracting or

scattering the light around the occluding rod so light will be picked up at the Scatter Cell, and less light will be received at the Transmit Photocell. It is this phenomenon which we exploit to measure the oil content. The Scatter Photocell light curve as a function of oil concentration is depicted above.

The amount of light received at the Scatter Photocell is



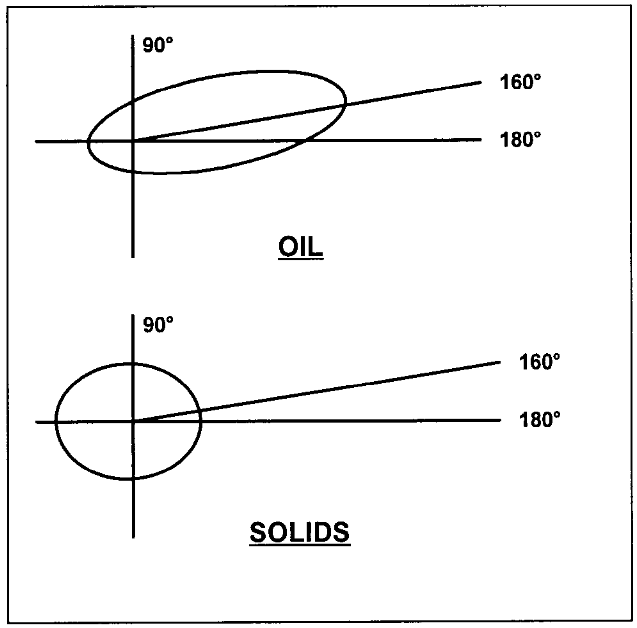
zero with no oil present [due to the occluding rod] and it increases with the oil content. Clearly, the light increases in a nonlinear way.

If we mathematically divide the transmitted light curve into the scattered light curve and plot the quotient as a function of concentration, we get a linear curve over a range of oil concentrations from 0 to 150 ppm. The electronics in the unit performs this calculation and converts the light received at the photo cells to oil content in ppm directly.

The theory of scattered light developed in 1908 by a Professor Mie applies in our case, i.e., visible light interacting with droplets larger than 1 micron in diameter. The Mie theory shows that the level of light from the Light Source which arrives at the Scatter Cell is dependent on the size of the oil droplets, the wavelength of the light and the angle of viewing. The amount of light that continues in a forward direction will be very high compared to light reflected back, as shown on the polar diagram below, which gives the amount of light arriving in each direction.

If solids are present, the light will not get through the solid. The solid is irregularly shaped so light will get trapped and be re-emitted in all directions. Then the curve is as shown below.

The polar curve is almost circular. Light coming in the 0° direction has almost as good a chance of winding up in the forward direction as in any other. If we have a Scatter cell at some position like 160° [almost straight ahead], the effect of oil will be to scatter much of the light there. The effect of solids would not particularly



favor the 160° position. So with equal amounts of oil and solids in the water, the length of the vector at 160° for oil would be very large compared to the length of the vector from an equal amount of solids, therefore the solids will have little effect. With twice as much solids as oil, the solid circle would still be smaller, at the 160° position, and there is still no problem. Only when the solid's content exceeds four times the oil content do we have inaccuracy in our measurements.

We look now at some of the threats to conventional oil monitors. We have already mentioned the solids and how we handle them. The second threat is the lamp age. The older the lamp, the less light it emits, and therefore the less light detected at each of the cells. Because we use a transmit photocell as a reference, reduction of the basic light level is canceled and not a problem, i.e., the ratio does not change.

Another factor is the bulb spectrum. Bulbs emitting in the ultraviolet will degrade much faster in the far UV than the near UV or visible range, given no compensation in the measuring circuitry. Therefore, we use only the visible. There is virtually no shifting in the spectrum as the bulb ages.

Another threat to other systems is dirt and algae growths on the window which reduce the amount of light in their optical systems. The reduction in light indicates incorrectly the presence of oil. In our system we clean off this build-up of dirt every 8 1/2 seconds by the reciprocating motion cleaning the Pyrex surface with a wiper, like a windshield wiper.

Another potential threat is that the oil in the stream can "plate out". A system in which the measurement is done 20 feet away from the pipe has a long run along which the oil can condense and not show up in the actual measurement. This gives an apparent low reading of oil. Our system is so small that it is mounted directly on the pipe. The problem of "plating out" does not occur.

Another threat to many systems is the type of oil. We have tested over a wide range of oil and found sensitivity to the type of oil [heavy vs. light] to be on the order of 20%, which is well within the guidelines established by EPA. These units measure animal and vegetable fats with similar sensitivity. Other systems have, in some cases, higher deviations.

The preceding discussion may be summarized by referring to three important factors for any instrument, namely, the accuracy, the reliability and the simplicity.

The accuracy is enhanced for the Oil Sentry by the fact that the relationship between the amount of oil and the amount of light is direct. It is not a complex relationship. The accuracy is also enhanced because the instrument is immediately adjacent to the fluid flow, giving an on- line reading. We are insensitive to extraneous factors like the presence of solids in concentrations of up to four times that of the oil. The reproducibility is excellent. We can repeat a measurement to within 2 percent.

As for the reliability of the instrument, there is only one moving part, the reciprocating piston. The system is made of corrosion-resistant stainless steel, Monel, and Delrin. All of the electronics, of course, are solid state. Reliability is built into the system by the use of very high grade materials and careful testing before it is shipped. A reflection of the reliability is the simplicity of the devices. It is very small, and has neither plumbing nor chemical complexity to go wrong.

In summary, we have discussed three important features of our device: self-cleaning, compactness and on-line measuring at the flow. We think that these tie in well with the three most important criteria in the selection of an Oil Content Monitor, namely that it be accurate, reliable and simple. When you make the decision about an oil monitor, please keep in mind how the self-cleaning, compactness, and on-line measuring relate to the reliability, the accuracy and the simplicity for your application.