Feature Article

Real-Time Monitoring of Oil Using Ultraviolet Filter Fluorometry

Slick Sleuth, Slick Guard Employ Noncontact Fluorescence Sensors for Autonomous Oil Slick Detection

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In the wake of the Deepwater Horizon oil spill in the Gulf of Mexico, prevention and response issues have taken on heightened importance and more public visibility. By utilizing automated spill detection sensors, oil spills can now be detected in real time. This early warning enables immediate response and containment of oil pollution, thereby reducing the volume of oil spilled and minimizing damage.

InterOcean Systems Inc. has developed a reliable, noncontact, highly sensitive oil detection sensor package, the Slick Sleuth. Existing users of this system include Shell Oil Co. (Houston, Texas), BP Plc (London, England), Petrobras (Rio de Janeiro, Brazil) and Exxon Mobil Corp. (Irving, Texas).

The Slick Sleuth is designed to provide remote and autonomous operation at a range in excess of five meters above the monitored surface (i.e., tidal range). Engineers have made the package adaptable, scalable and easy to install and operate. Key system attributes include near-zero maintenance and micron-level sensitivity for a comprehensive range of oils. The system can be installed in a number of environments, including industrial facilities, ports, harbors, coastal areas and offshore. The automated, self-contained sensor systems are either mounted to fixed structures, such as piers, or affixed to buoys, such as the recently developed Slick Guard monitoring platform, which is designed for real-time detection and alert in the near-shore and offshore environment.

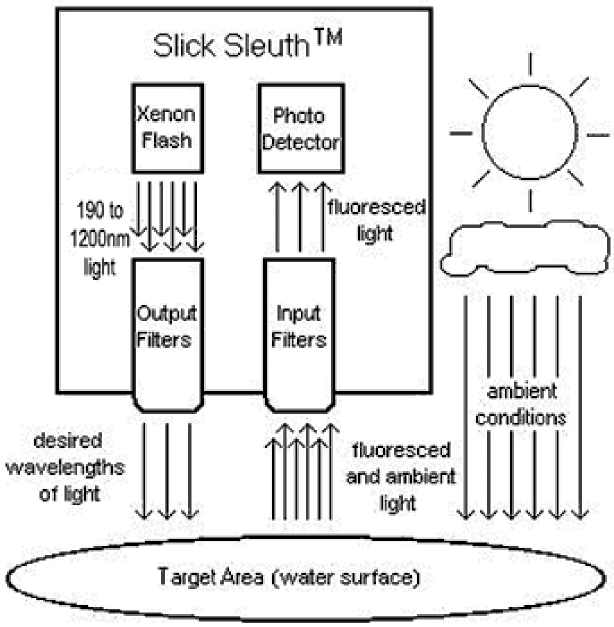
A Slick Guard monitors the water intakes for a desalination plant and a power plant. This system is currently installed in the Middle East.

Ultraviolet Filter Fluorometry

Oils are known to fluoresce, an optical phenomenon in which a compound absorbs light at one wavelength and emits it at a longer wavelength. Because some rotational-vibrational energy is lost in the absorption-emission process, the wavelength of the emitted light is always longer than the wavelength of the absorbed light.

Typically the absorbed light is in the ultraviolet (UV) range and the emitted light is in the visible range, with the longer wavelengths often appearing violet or blue. As an example, oils typically absorb light between 300 and 400 nanometers and emit light in the 450-to-650 nanometer range.

Fluorescence detection, or fluorometry, is by no means new. Existing fluorometers use spectroscopy methods for fluorescence detection in the form of flow-through or in-water systems comprised of sophisticated lab-quality instruments used for scientific research or as water analyzers. These fluorometers tend to be quite expensive and impractical for use as remotely deployed field units or for use as a networked array of remote monitors. Flow-through and immersion techniques are also susceptible to biofouling and oil staining on the sampling tube or optical mechanism and thus require significant maintenance. Likewise, floating or submerged in-water sensors and probes have drawbacks such as problematic biofouling and troublesome installation and maintenance issues.



Basic operation of Slick Sleuth sensor.

Slick Sleuth Design

The Slick Sleuth is noncontact, remotely deployable and uses downward-looking optical sensors. The sensor may be installed high above target surfaces, thus freeing it from excessive maintenance, fouling effects and deployment limitations. These characteristics make it favorable for field installation and remote detection of oil on water.

The system's field-deployable UV-optical sensors incorporate a high-energy light source, filtered and sharply focused into a conical beam so that only desired wavelengths of light are projected onto the target area. Any oil present in the target area will fluoresce and radiate light of characteristic wavelengths, which is processed by the UV-sensor's proprietary scanning optics and digital signal processing system, thus detecting the fluorescence characteristic of oil.

Technical Development

Development efforts focused on oils and petroleum-based fluids. Crude oils, heavy fuel oils, lube oils, motor oils, hydraulic oils, turbine oils, diesel, jet fuel and kerosene were all tested, and all proved to be readily detected.

There is inherent variability in fluorometric characteristics and how various hydrocarbons and oil types will respond to the detector when excited with UV light. Rather than attempting to analyze small differences and degrees of variability between every type of oil in every possible concentration and state, priority was given to developing a field sensor capable of qualifying the presence of the widest possible range of oils with high reliability and detection probability. This broad-range detector can also then be optically "tuned" to focus on specific oil types of concern.

As the result of experimentation during research and development, a high-powered xenon strobe was selected for the sensor's light source, which has proven highly effective throughout the sensor's evolution. The strobe provides enough output intensity to enable detection of small surface sheens from a distance of five meters above the target surface area. Ongoing research and development, along with advances in optics, are yielding promising results for applications such as offshore platforms, with detection ranges upward of 20 meters possible in the near term.

Other integral components comprising the optical assembly are parabolic reflectors that focus the conical beam onto the target area below and band-pass filters that limit the energy output to the desired spectral range. On the detector side, band-pass filters are coupled with proprietary photo detectors optimized for accurate detection of a wide range of oils.

The sensor system can be powered by alternating current or direct current from solar panels and rechargeable batteries. All sensor components are housed in a stainless steel weatherproof enclosure measuring roughly 20 by 30 by 40 centimeters. Valve fittings and a vent allow an air purge to be added to satisfy installation requirements in hazardous gas locations, or the sensor may be installed within an explosion-proof housing.

Remote communication of detection alarms is accomplished using contact relays, analog 4-20 milliamp current output, RS-232, RS-485 or a combination of any of these. Depending on application requirements and available infrastructure, these outputs are accessed via hardwire or wireless methodologies for real-time event notification to a central control room, security post, cell phone and/or e-mail address.

Alarm output can also be used to automatically control a valve or activate/deactivate a pump or skimmer, providing immediate, fully automated containment of a spill prior to any human intervention. This automated, fail-safe method of detection and control ensures that accidental spills are contained on site, with personnel alerted and no oil reaching the environment.

Sensor Performance

One of the challenges of using an optical sensor is that it must have a clear view of the sampling area. If the optical path is blocked, the detector's effectiveness can be compromised. Testing and field experience have demonstrated that the UV light beam is unaffected by haze or fog and has not presented any problems in the many field installations to date.

Similarly, partial path interference by physical blockage, such as metal grating, does not necessarily disable the sensor's ability to detect oil. Numerous industrial users have taken advantage of the capability to optically monitor for oil through a grate, while others simply cut a small window in the grate to provide an unobstructed optical path.

While the sensor is optimally mounted perpendicular to the surface below, it has been determined that the sensor may also be tilted at an angle. This attribute is critical in certain applications, such as floating installations, where a fixed perpendicular orientation is not viable.

In many cases, the Slick Sleuth has also been able to detect oil dispersed in water, as well as fluorescing compounds such as glycols that are water soluble.

The sensor is user-programmable for variable sampling, from a continuous two-hertz sampling mode (for monitoring fast-moving currents) to a periodic sampling mode in which the instrument takes a burst sample (typically 10 samples at 100-millisecond intervals once every five seconds) and the detector analyzes an average of this periodic burst sample.

Spill sensors are mounted on the outer circumference of an offshore tanker loading buoy. Two sensors are mounted on opposite sides of the buoy. Oil-on-water alarms are relayed to the tanker vessel to provide near-instantaneous alert of oil spills

Sensor Accuracy

One of the biggest concerns of sensor operators is false detection, and there are a few substances that fluoresce in a manner similar to petroleum-based fluids. In the case of some non-oil chemicals known to fluoresce—for example, particular fluids containing rust inhibitors—varying the optical excitation frequency (optical filtering) has been successful in eliminating this potential source of false detection. More commonly, wildlife such as birds, algae, seaweed, sea foam, driftwood, debris and plastic bags may be present, but none have proven to be problematic sources of false detection. The Slick Sleuth has also not been affected by ambient conditions, such as varying sunlight, waves or water currents.

During sensor initialization, a baseline measurement is made to establish normal operating conditions, either with clean water or with a normal amount of oil present.

Varying water level, such as tides or stormwater, cause the ambient baseline to shift up or down as the water periodically rises and subsides. As such, in cyclical tidal settings or applications where stormwater surges occur randomly, the sensor uses an algorithm referred to as "adaptive baseline mode" to compensate.

EPA Compliance

A notable milestone for the Slick Sleuth was being certified for compliance with the U.S. Environmental Protection Agency's (EPA) "Standard Test Procedures for Evaluating Leak Detection Methods." The EPA mandates that a facility must maintain a spill prevention, control and countermeasure plan that documents potential spill sources and risks and includes prevention and monitoring measures at the site. Facilities must also maintain contingency response equipment and capabilities. These regulations apply to all facilities with above-ground storage of any types of oil of more than 1,320 gallons aggregate or any single tank larger than 660 gallons.

When implemented, Slick Sleuth sensors are included as part of a user's or facility's spill prevention and control planning and capabilities.

Application Examples

Initial development of this oil spill detection system was driven by user requirements in port and harbor settings, where sensors can be strategically placed to monitor fuel piers and bunkering facilities, marine terminals, shipyards, naval installations, stormwater outfalls, etc. However, many of the early-adopters of this spill monitoring technology have proven to be industrial users, such as refineries, power plants, and steel mills, which need to monitor effluent outflow for the presence of oil prior to discharge into public waterways.

Today there is tremendous interest in oil spill monitoring for coastal and offshore environments and activities, particularly given ever-increasing offshore drilling ventures and public outcry over the Deepwater Horizon spill. Oil spill monitoring can improve early warning alert and response capabilities for production sites to help prevent or minimize the risk of ecologically catastrophic events.

Another application is early warning oil spill protection of seawater intakes at desalination plants. A growing number of desalination plants requiring oil spill monitoring led to the development of the Slick Guard system, which provides real-time oil-on-water alert before oil can reaches the plant's intakes. The Slick Guard system can also provide a platform for other environmental monitoring sensors such as wind, current, waves, salinity, etc.

In addition to spill monitoring in harbors or installing spill alarm safeguards along industrial spillways, another major application involves the use of remote spill detection sensors for protection of sensitive wildlife habitats and aquaculture. For this application, detectors are installed beyond the perimeter of a sensitive habitat, such as an estuary, wetlands, mangrove, bird sanctuary or shellfish bed. If a spill encroaches upon the boundary of a protected area, the remote spill detector will alert designated personnel. This triggers contingency response actions in time to avert potentially catastrophic damage to wildlife and natural resources. A spill-alert notification in real time, day or night, allows responders to deploy oil containment booms and to implement preplanned time-critical response activities.

Conclusions

Noncontact UV spill detectors are now being used successfully in various regions throughout the developed and developing world. Numerous instances have been reported in which the Slick Sleuth sensor has performed as intended and successfully detected potentially harmful spills.

End users and new applications are driving further development of this technology. Research and development is ongoing to refine and continuously improve system performance, increase detection capabilities, and meet new demands for applications in the offshore environment and in sensitive habitats, such as wetlands and mangroves.

As with the proliferation and widespread adoption of any new technology, a key component going forward will continue to be increased awareness of the availability and benefits of new sensor technologies, remote spill alarms and related spill abatement technologies as integral components of spill prevention and response strategies.

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