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April 17, 2014  
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## PetroSense® Hydrocarbon Sensors and their Applications

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### Introduction

The increasing concern about hydrocarbon contamination of process water and produced water has created an increasing need for in-situ, real time, and accurate low cost instrumentation that can provide rapid detection and easily usable in the field.

PetroSense Sensors represents "best in breed" technology for the detection of total petroleum hydrocarbons (TPH). PetroSense Sensors are incorporated in both a portable, field screening instrument (the [Portable Hydrocarbon Analyzer PHA-100](#)) and our continuous monitoring systems. These sensors utilize fiber optic systems and are designed for in-situ, real time measurements of TPH and other related pollutants.

### Petrosense Sensors Operate in Vapor, Water and Soil

PetroSense Sensors are non-specific detectors for TPH, semi-volatile hydrocarbons (e.g., diesel fuel, heating fuels, etc.), trichloroethylene/perchloroethylene and many other related compounds. The detection capability of these sensors is unaffected by high humidity, or by naturally occurring methane.



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## Petrosense® Sensors Have Been Used In A Variety Of Applications:

- Leak detection for above ground and underground storage tanks
- In-situ vapor measurements in wells
- In-situ water measurements in wells
- Water measurements in bailed samples from wells
- Surface water measurements
- Tracking of a hydrocarbon leak in progress (plume migration)
- In-situ monitoring for vapor extraction systems
- Leak detection for pipelines
- Storm water runoff monitoring
- Sample screening for laboratory analyses
- Site assessment
- Groundwater remediation

Although these sensors are non-specific, there is a relative response characteristic for the different compounds that are detected. The **PetroSense Sensors** have a very strong response for aromatic and other large hydrocarbon compounds. **This makes these sensors very useful for the detection of BTEX (benzene, toluene, ethyl benzene and xylenes), which is used as a tracer for TPH leaks/contamination.** The characteristic relative response factors (RRF's) can be determined for specific sites. The sensors can be calibrated for specific compounds expected at a given site, or the non-specific readings can be converted to the concentrations of these specific compounds by use of the appropriate RRF's.

*All of the PetroSense products are designed to be intrinsically safe and can be used in most hazardous environments.*



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## PetroSense® Hydrocarbon Sensor Technology

PetroSense Sensors represent a fiber optic sensor based technology for the detection of total petroleum hydrocarbons (TPH). PetroSense Sensors are incorporated in both a portable, field screening instrument (the [Portable Hydrocarbon Analyzer PHA-100Plus](#)) and our **continuous monitoring systems for the monitoring of vapor and dissolved hydrocarbons in water**. These sensors utilize fiber optic systems and are designed for in-situ, real-time measurements of TPH and other related pollutants.

The principle behind the PetroSense Technology is the modulation of light guided along an optical fiber. Optical fibers are utilized for the transmission of light based upon the phenomenon of total internal reflection.

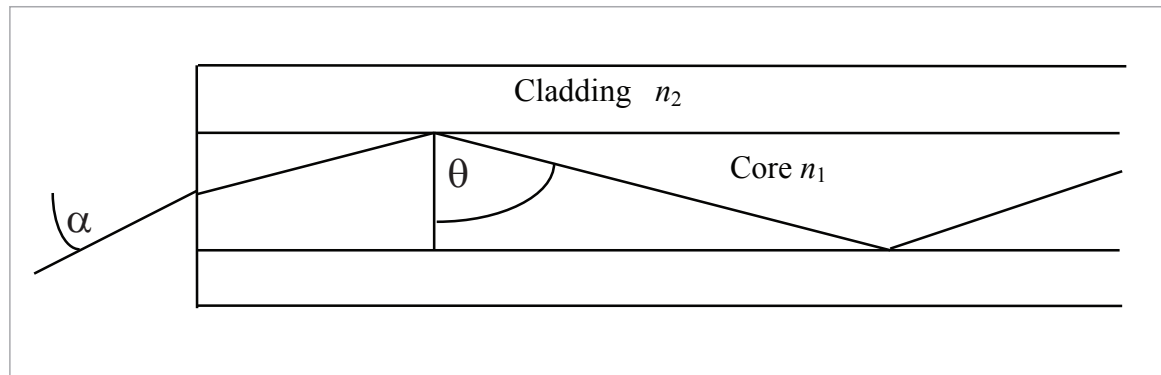


Figure 1. Schematic of an optical fiber:  $\alpha$  is the acceptance angle;  $n_1$  and  $n_2$  are the refractive indices.



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Light entering the end of a fiber optic is completely reflected within the fiber and therefore transmitted through the fiber, if it strikes the core of the fiber with an incident angle greater than a characteristic critical angle  $\theta$ . This critical angle is determined by the refractive indices ( $n$ ) of the glass and the surrounding medium. By cladding the fiber optic core with materials with certain refractive indices, the amount of internally reflected light can be optimized.

The relationship of this critical angle and the refractive indices can be approximated by the following equation based upon the half-angle of the incident light,  $\alpha$ :

$$\sin \alpha = \frac{(n_1^2 - n_2^2)^{1/2}}{n_0}$$

When the outer medium is air,  $n_0$  is 1. It follows that the refractive index of the cladding ( $n_2$ ) is key in the transmission of propagated light. If the cladding material were to be replaced by a coating that acted like a cladding but also changed its optical properties, like refractive index, due to the presence of certain chemicals in the environment; then we would have a very powerful sensor.

The proprietary cladding utilized on the PetroSense Sensors is sensitive to petroleum hydrocarbons in the surrounding medium; this results in a hydrocarbon sensor.

When hydrocarbons absorb to the surface of the cladding of the fiber, the resultant change in the cladding refractive index ( $n_2$ ) alters the amount of transmitted light. Very small changes in the refractive index can yield relatively large changes in transmitted light; these changes can be measured and calibrated to represent concentrations of species (e.g., TPH) present in the surrounding medium.

### Petrosense Sensors Can Measure Hydrocarbons in Vapor as Well as in Water

As an example, the detection capabilities for the **PetroSense Sensors for BTEX mixtures are 0.1 ppm dissolved in water, and 10 ppm in air.** The lower detection limits for various hydrocarbons are shown in *Table 1*. As this sensor measures changes in the refractive index of the cladding it has a very large dynamic range. Measurements can be made from as low as a few ppm all the way up to saturation of hydrocarbons in air or water.

*Third party testing has shown that the PetroSense Hydrocarbon Probe has a greater than 95% correlation to a GC when measuring hydrocarbons under laboratory conditions.*



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Table 1

Lower detection limits for various hydrocarbons of the PetroSense® Hydrocarbon Sensors.

The coated fibers are built into probes (**AHP-100, and DHP-485**) that have the necessary electronics to convert the optical changes in the fiber to electronic signals that can be logged using a data logger.

The probes are potted to allow the sensors to be used in water.

Compounds	LDL for water (ppm)	LDL for Vapor (ppm)
Xylenes (p, o, & m)	0.13	9.78
Benzene	0.38	54.45
Toluene	0.30	22.45
1,2,4-Trimethylbenzene	0.10	20.00
Ethyl Benzene	0.10	9.59
Trichloroethylene	5.00	65.00
Tetrachloroethylene	1.50	35.00
Unleaded Gasoline	0.40	3.00
Diesel	0.44	4.00
Kerosene	0.30	7.40
JP4	0.90	5.30
JP8	0.81	7.50
Bunker C/Num 6	0.35	3.00



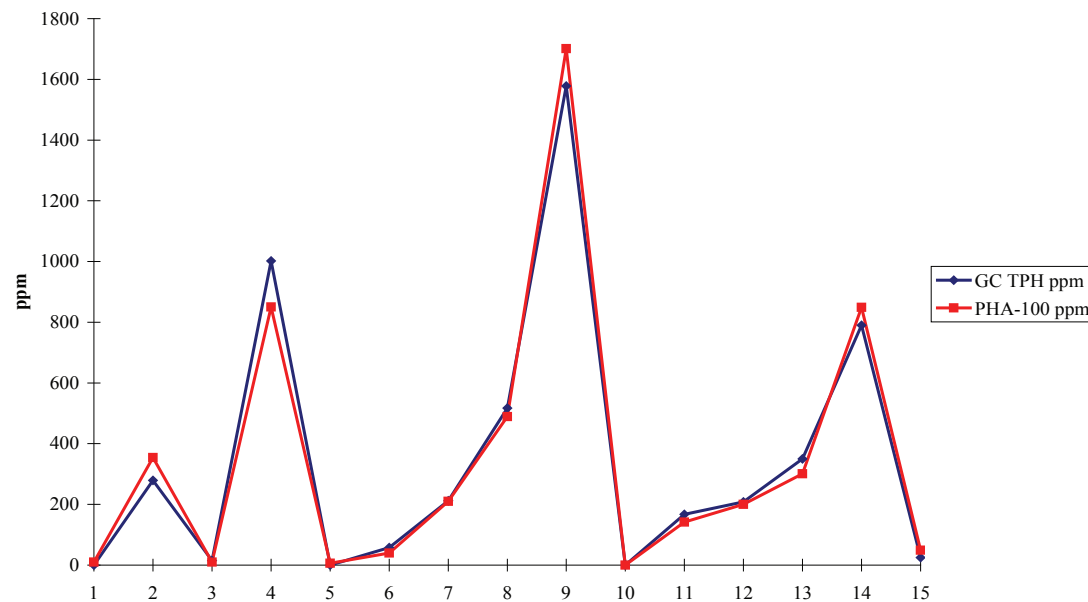
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Figure 2: *PetroSense Digital Hydrocarbon Probe*

These probes are used with various instruments such as the PetroSense CMS-4000 that has a data logger that can be connected to 4 probes. These probes can be left in-situ (in real time) for continuous monitoring of the environment for hydrocarbons. The data logger has a modem so that the data can be retrieved by telephone from the office. The probes are also used with a field portable instrument the PetroSense Portable Hydrocarbon Analyzer PHA-100. These instruments show very good correlation to GC analysis of hydrocarbons (Graph 1).



Graph 1.  
 Hydrocarbon vapor samples measured with a PetroSense probe in-situ (in real time) measurements and GC analysis



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## PetroSense® Hydrocarbon Sensor Technology

### Summary

The use of fiber optic chemical sensor technology has allowed the creation of a unique sensor that is capable of measuring low levels of hydrocarbons in vapor and water.

The PetroSense Sensors are unique because the measurements can be made in-situ and in real time. This reduces errors from sampling as well as reducing analysis costs.

The PetroSense instruments are being used in a number of applications where hydrocarbons need to be monitored. They are finding wide acceptance by the oil industry as well as the environmental monitoring industry. The uniqueness of these sensors allows them to be used in process control and environmental monitoring. These sensors can be used either in vapor and water or in most environments where hydrocarbons are encountered.

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