

# THEORY AND OPERATION OF NDIR SENSORS

## THEORY OF NDIR

The MultiRAE IR monitor uses an NDIR (non-dispersive infrared absorbance) sensor to monitor CO<sub>2</sub>. Most molecules can absorb infrared light, causing them to bend, stretch or twist. The amount of IR light absorbed is proportional to the concentration. The energy of the photons is not enough to cause ionization, and thus the detection principle is very different from that of a photoionization detector (PID). Ultimately, the energy is converted to kinetic energy, causing the molecules to speed up and thus heat the gas. A familiar IR light source is an incandescent household bulb. Each molecule absorbs infrared light at wavelengths representative of the types of bonds present.

For example, CO<sub>2</sub> has a strong absorbance at 4.26 μm (2350 cm<sup>-1</sup>, Figure 1), and C-H bonds absorb in the range 3.3-3.5 μm (2800-3000 cm<sup>-1</sup>, Figure 2), depending on the structure of the rest of the molecule. The CO<sub>2</sub> absorbance band is unique and therefore highly selective. By contrast, many compounds have similar C-H bonds, and this absorbance is suitable to detect a range of hydrocarbons non-selectively. Comparing Figures 1 and 2, one can see that there is no interference by gasoline absorbance in the CO<sub>2</sub> measurement, because gasoline has no absorbance at 4.26 μm (2,350 cm<sup>-1</sup>). The absorbance of the gas is directly proportional to its concentration, in accordance with the Lambert-Beer law:

$$A = \epsilon lc$$

$$I = I_0 10^{-A} = I_0 10^{-\epsilon lc}$$

Where  $I_0$  is the initial light intensity emitted from the lamp (measured in pure air),  $I$  is the intensity of light reaching the end the detector (with sample gas present),  $A$  is the absorbance in units of length<sup>-1</sup>,  $\epsilon$  is the molar extinction coefficient in concentration<sup>-1</sup> length<sup>-1</sup>,  $l$  is the pathlength (sensor cavity depth), and  $c$  is the concentration. Because  $l$  and  $\epsilon$  are fixed, measuring the light intensity before and after the sample allows a measurement of the concentration.

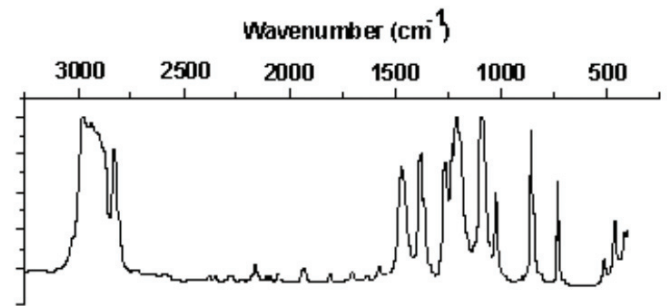


Figure 2. IR Spectrum of Gasoline.

## NDIR SENSOR DESIGN

Figure 3 shows a top view of the overall NDIR sensor design. The gas sample diffuses in through a metal frit in the top. Polychromatic light from the incandescent bulb passes through the gas sample and is absorbed in proportion to the amount of CO<sub>2</sub> present. Reflection of light off the internal walls increases the pathlength,  $l$ , thus increasing sensitivity. The filter in front of the detector removes all the light except that at 4.26 μm, corresponding to CO<sub>2</sub>.

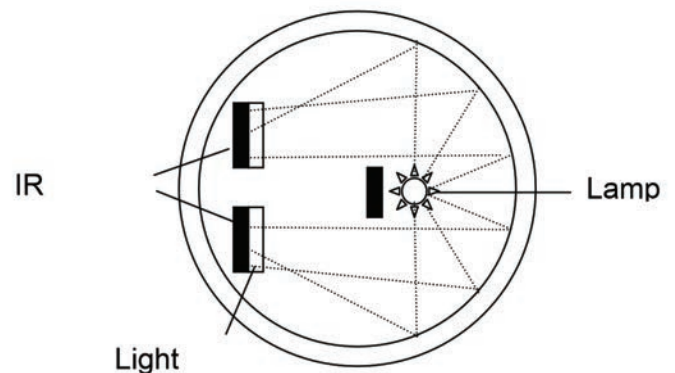


Figure Top view schematic diagram of NDIR Sensor.

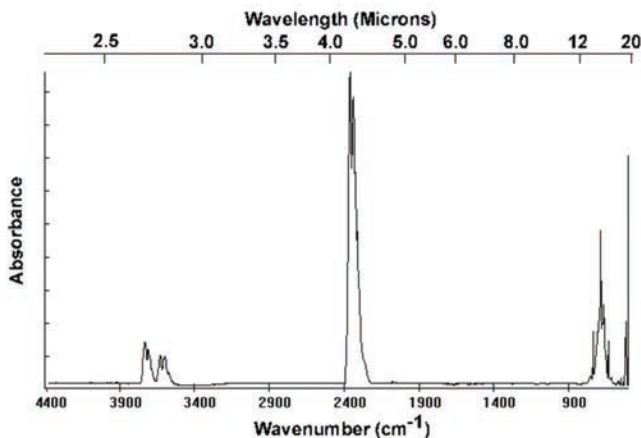
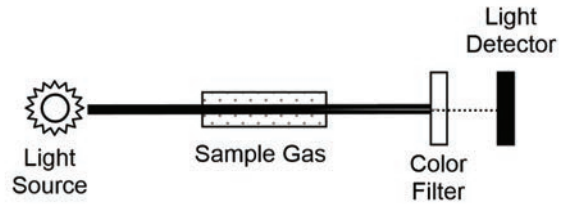


Figure 1. IR Spectrum of CO<sub>2</sub>.

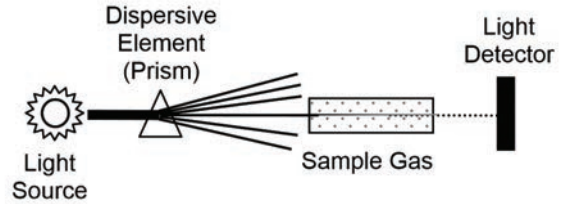
By varying the light filters, it is possible to select for different classes of compounds. Typically, a 3.4  $\mu\text{m}$  filter is used to select for hydrocarbons.

**Non-Dispersive vs Dispersive IR Sensors**

The term non-dispersive refers to the fact that all the light passes through the gas sample and is only filtered immediately before the detector. Dispersive IR detectors use a grating or prism to pre-select the desired wavelength of light and pass only this through the gas sample to the detector. Dispersive IR detectors are usually used in benchtop analytic instruments for their ability to scan a broad wavelength range. However, they tend to be larger, heavier, more complicated, and more costly, and therefore are less suitable for portable instruments.



**Figure 4. Non-Dispersive IR – All light goes through sample.**



**Figure 5. Dispersive IR – Only selected wavelength light goes through sample.**