FISO offers unique solution for Oil Concentration Ratio measurement

APPLICATION NOTE

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Over recent years, many factors have increased the demand for a better energetic efficiency of cars, domestic appliances and, of course, cooling systems.

The Kyoto protocol is clearly leading to a reduction of Greenhouse gases that cause climate changes. Closer to our day-to-day concerns is the increasing cost of energy. The demand for energy (oil, natural gas, electricity) is growing everywhere in the world, mainly driven by newly industrialized countries. This increased demand explains the significant rise in the price of energy (electricity & oil) that we witnessed over the past months. How does it affect the community of engineers working in refrigeration, and how can they react? A significant part of the solution is to improve the efficiency of newly designed and manufactured cooling systems.

The Effect of Oil in Refrigerants

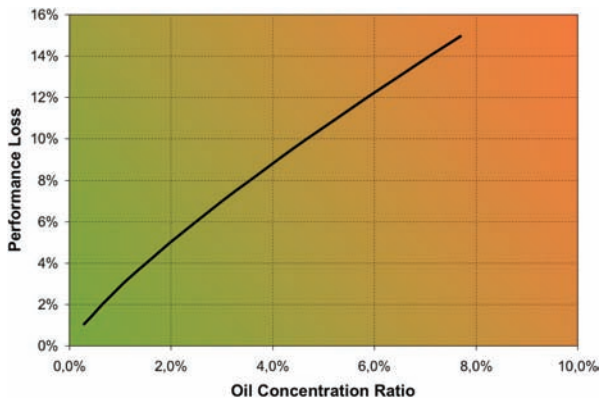
A lot of researches have been conducted to link the effect of Oil Concentration Ratio (OCR) to the efficiency of a cooling system. In fact, this oil, which acts as a compressor lubricant and as a sealing, will inevitably find its way through the complete system. Even if only a small trace of oil is detected in the system, the quantity will surely increase with time and extended wearing of mechanical components. How does it become a concern? Many studies have demonstrated that a small amount of oil in the refrigerant will increase the efficiency of the system, but that when the oil content of the mixture reaches a given level, the performance will drop drastically. Some systems will even see their efficiency decrease with only a very low amount of oil (<1%) in the mixture. It is well-known that the heat transfer is affected by the refrigerant, the oil type and, of course, by the tube bundle design. Even small concentrations of oil in refrigerants will have a tremendous impact on the evaporating heat transfer coefficient. From the results of study RP-751 from ASHRAE, we can clearly assess the importance of the OCR on the heat transfer (see data of Table 1*). Depending on the refrigerant and oil type, the effect could be dramatic. The heat transfer coefficient reduction represents 30% with 1-2% of oil in R-134a refrigerant and could rise up to 40-50% of reduction with 5-15% of oil content.

TABLE 1: Typical oil level and their effects on systems performance*

Oil in evaporator	Performance Loss
1% to 2%	2% to 4%
3% to 4%	5% to 8%
5% to 6%	9% to 11%
7% to 8%	13% to 15%

** ASHRAE (2007). ©American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., www.ashrae.org.*

Figure 1: Effect of the OCR on the system performance



To adequately control the efficiency of HVAC system, it is mandatory to manage the level of oil in the refrigerant. The accurate management of the oil concentration ratio will improve the systems' efficiency and decrease the cost of usage. The first action to take to facilitate the regulation of the OCR is to precisely measure the OCR.

The measurement of the oil concentration ratio will bring many benefits. Not only when used in the design phase of new systems tested on calorimeters and qualification benches, but also for continuous monitoring of HVAC systems. The values obtained during the design phase will be used in the selection of new and environmentally-friendly refrigerants, in the qualification of new bundle designs, in the performance evaluation of oil separators & purgers, in the development of maintenance programs and so on. As for the continuous measurement of the oil concentration ratio, it can be used to schedule maintenance at the right moment so as to decrease the downtime caused by repair, give indications on the performance of the oil separator and the purger as well as help in the control and understanding of the system.

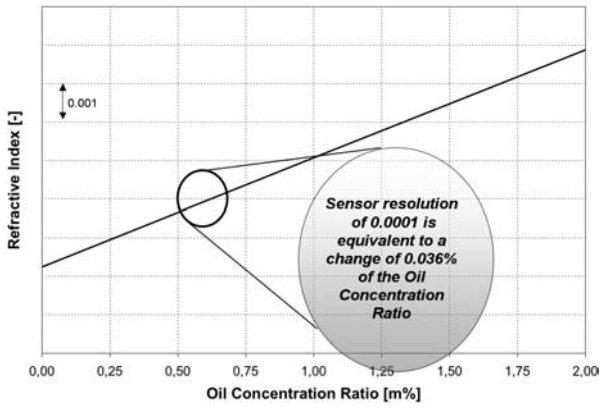
Effective measurement of the Oil Concentration Ratio (OCR)

The most common method used to measure the content of oil in a refrigerant is by sampling and weighting. However, this method is time-consuming, removes a certain amount of oil and refrigerant in the system and, of course, the result obtained does not reflect real-time phenomena. Therefore, many people tried to develop alternative ways to this classic method to clearly quantify the exact composition of the mixture. Over the years, a lot of technological paths have been investigated to achieve a successful real-time measurement of the concentration of the working fluid in refrigeration systems. These methods cover a wide spectrum of technologies; from liquid density measurement to acoustic velocity, going over light absorption, dielectric constant and finally, refractive index measurement. However, not all of these technologies will give entire satisfaction and convince that the result is exact, reliable and therefore, valuable.

FISO Technologies inc. developed a system which allows engineers to accurately measure the oil concentration ratio using a refractive index fiber optic sensor (FRI) and its signal conditioner. The proposed solution clearly covers the main requirements expressed by engineers working on cooling systems:

- First, it can achieve a resolution better than 0.04% of oil concentration ratio. Recent series of experiments, jointly performed by *Danfoss Commercial Compressor*[1] and a third-party laboratory, showed that the FRI fiber optic sensors, when used with the FTI-10 signal conditioner, were sensitive enough to detect a change of 0.036% of POE oil in the R-410A refrigerant.

Figure 2: Refractive index change with R-410A & POE



1. Material provided by DANFOSS COMMERCIAL COMPRESSORS with permission from DANFOSS COMMERCIAL COMPRESSORS, understanding that the material will neither imply nor state that DANFOSS COMMERCIAL COMPRESSORS endorses a commercial product or service.

- Secondly, an easy installation of the sensor into the cooling system is helpful. The FRI-NP sensor is mounted in a stainless steel rod (1/8") which is supplied with a *Swagelock*® NPT fitting. Some customers prefer to use their own connector (from *Conax Technologies* or others), which are usually very easy to fix on the SS sensor rod. With this installation method, the system disturbance is minimal and results perfectly reflect the phenomenon. When needed, the bare version of this refractive index sensor (FRI-BA), having less than 0.032 in of diameter (0.8 mm), allows an access to small tubes or to specific areas that cannot be reached with the FRI-NP model. Both sensor designs allow an effective in-situ continuous measurement directly at the location of interest.
- Moreover, the acquisition rate and channel number of the system should easily be adaptable and flexible. While the FTI-10 is a stand-alone unit with a 10 Hz sampling rate, some multi-channel reading units (UMI-4 or UMI-8) offer respectively 4 and 8 points for refractive index measurement. It is well known that during the design phase of a new system, it is interesting to measure how the oil concentration ratio varies from one location to the other in the cooling system. Having multiple points of measurement, all logged by a single signal conditioner, is therefore advantageous. Depending on the speed of the transient phenomenon and the test duration, the sampling rate and the bandpass filter can be modified to optimize the results. These adjustments can be done by using the *FISOCommander* software or through RS-232 commands. Following the configuration of the system, the customer will have the data in a text format, which eases the treatment and interpretation of the test results. In addition, an analog output is also available for scientists who have their own data acquisition system.
- Finally, the white-light Fabry-Pérot technology used by the signal conditioner unit is highly tolerant to light losses and fluctuations caused by small bending radius of the optical fiber, long distance and multiple connections. A sensor diagnosis performed by the conditioner provides extra indications of the sensor's status before starting a series of tests.

In addition to these points, FISO Technologies inc. offers a wider range of solutions for engineers working in instrumentation. We offer fiber optic sensors and conditioners for temperature, pressure and strain measurement. With accuracy as good as 0.15°C and pressure resolution down to 50 Pa, many problems can be solved. The company offers various signal conditioners, including a single channel at 10 Hz, some multichannel systems having up to 32 channels at 20 Hz as well as a high-speed unit at 200 kHz. This variety of configurations is well-liked by engineers and scientists involved in laboratory, instrumentation, metrology and in-field applications. Moreover, it is important to note that sensors of different parameters can be read by the same signal conditioner, adding another remarkable feature to our already versatile solution.

About FISO Technologies inc.

FISO Technologies Inc. is a leading developer and manufacturer of fiber optic sensors for physical and chemical parameters. We are committed to provide customers with innovative and reliable solutions for measuring parameters in harsh environments and challenging applications. Besides being extremely small, the advantages of fiber optic are that they are highly precise, intrinsically safe, minimally invasive (nano technology) and immune to radio frequencies, electromagnetic interferences and microwave radiation. FISO's targeted markets are process control, medical, aerospace & defence, energy, scientific and academic.

The products are designed by experienced engineers and technicians who always have in mind the needs of our customers. We know that our customers are working in challenging environments and need products that are based on cutting-edge technology. One of our strongest competitive advantages is to be able to respond quickly to what our customers require and customized, if necessary, our existing solutions. We strive as strongly as our customers to offer the best products and technologies.

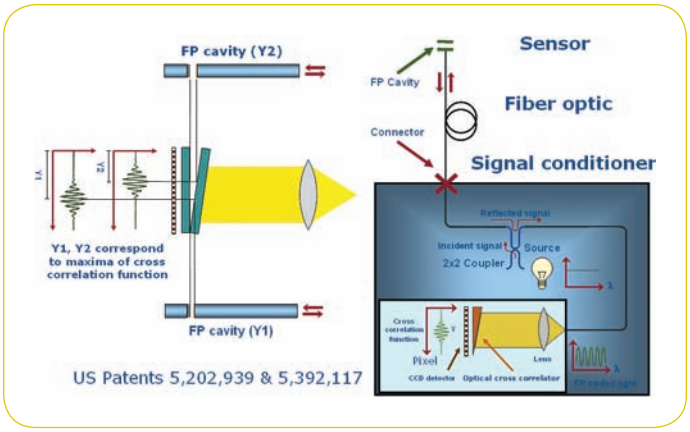
Founded in 1994, the company is part of the Roctest Group (RTT), a publicly traded company in Canada. Its products are sold in more than 75 countries through a network of representatives and distributors. Since 2003, FISO Technologies meets the requirements of the ISO 9001:2000 certification. The company is assessed and certified by SGS since 2005 and strictly applies its quality policy day after day by providing products and services which meet the specified requirements while directing efforts to satisfy its customers' needs.

Sensor technology

FISO's solution to quantify oil content in refrigerant is based on refractive index measurement. While the fiber optic sensor is installed in the mixture, the liquid fills the cavity and the optical length varies in direct proportion with the refractive index (RI) of the fluid. The measured RI corresponds to the effective refractive index as covered by the spectral distribution of the signal conditioner's light source, which center wavelength is located around 800 nm. As a first step, the user calibrates and correlates the given index of refraction measurements with reference oil/refrigerant samples. Then, these initial data will be used to create a calibration equation or calibration table. Even if the system performs measurements on a very large range of oil concentration, it is recommended to limit the calibration range in order to increase the accuracy.

Signal conditioner technology

FISO Technologies inc.'s patented **white-light cross-correlator** offers a unique and powerful way to make absolute Fabry-Pérot cavity length measurements with astonishing accuracy and linearity, providing consistency time after time. Light from a broadband source is launched into one arm of a 2 x 2 coupler and directed toward the Fabry-Pérot gauge. The light signal, which is wavelength-modulated by the gauge, is reflected back toward the signal conditioner, focused on a line, transmitted through the patented white-light cross-correlator and detected by a linear CCD array. The white-light cross-correlator can be described as a spatially-distributed Fabry-Pérot cavity in which the cavity length varies along the lateral position. Facing the CCD array, each pixel is associated with a predefined Fabry-Pérot-like cavity length. Thus, the device works like an optical cross-correlator with a spatially varying cavity length. For instance, consider a Fabry-Pérot gauge with a cavity length of d µm. The light reflected by this gauge will be transmitted maximally at the pixel of the CCD array with which a Fabry-Pérot cavity of d µm is associated, i.e. at the lateral position where the spatially-distributed Fabry-Pérot cavity is equal to d µm. As shown below, a variation of the Fabry-Pérot cavity length is converted into a displacement of the pixel that sees the maximum transmission. This technique provides accurate and reliable measurements of the sensors' cavity length. FISO Technologies inc. makes use of a fully-integrated optical cross-correlator based on the deposition of a shaped dielectric coating. The accuracy is guaranteed over a wide range of temperatures and for long periods of time.



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