EXECUTIVE SUMMARY

FINAL REPORT ARTI-21CR/611-50060-01
USING ACID NUMBER AS A LEADING INDICATOR OF REFRIGERATION AND AIR CONDITIONING SYSTEM PERFORMANCE

Air conditioning and refrigeration equipment needs to provide long-term reliable use. However, over long periods of time, stress induced deterioration of the refrigerant and/or lubricant will occur which can cause changes in the system chemistry resulting in decreased operating efficiency and potentially can lead to a failure of the system. A number of degradation processes contribute to the deterioration and are reflected by changes in parameters such as acidity, moisture content, viscosity, dissolved metal content, etc., which are all related to the formation of increasing amounts of acids over time. Total acid number (TAN), which includes both mineral acids and organic acids, is therefore a useful indicator which can be used to monitor the condition of the system in order to perform remedial maintenance, when required, to prevent system failure. A literature review was performed to assess the acidity characteristics of the older mineral oil and newer polyolester (POE) refrigeration systems as well as to evaluate acid measuring techniques used in other non-aqueous systems which may be applicable for refrigeration systems.

Failure in the older chlorofluorocarbon/hydrochlorofluorocarbon (CFC/HCFC) / mineral oil systems was primarily due to thermal degradation of the refrigerant which resulted in the formation of hydrochloric and hydrofluoric acids. These are strong mineral acids, which can, over time, severely corrode the system metals and lead to the formation of copper plating on iron surfaces. The oil lubricants used in the older systems were relatively stable and were not prone to hydrolytic degradation due to the low solubility of water in oil.

The refrigerants in the newer hydrofluorocarbon (HFC)/POE systems are much more thermally stable than the older CFC/HCFC refrigerants and mineral acid formation is negligible. However, acidity is produced in the new systems by hydrolytic decomposition of the POE lubricants with water to produce the parent organic acids and alcohols used to prepare the POE. The individual acids can therefore vary but they are generally C_5 to C_9 carboxylic acids. Organic acids are much weaker and far less corrosive to metals than the mineral acids from the older systems but they can, over long time periods, react with metals to form carboxylic metal salts. The salts tend to accumulate in narrow areas such as capillary tubes, particularly if residual hydrocarbon processing chemicals are present in the system, which can lead to plugging.

The rate of acid production from POEs varies on a number of factors including chemical structure, moisture levels, temperature, acid concentration and metals. The hydrolysis rate of reaction can be reduced by using driers to reduce the free water concentration and by using scavenging chemicals which react with the system acids.

The critical TAN value is the acid level at which remedial action should be taken to prevent the onset of rapid acid formation which can result in system failure. The level of 0.05 mg KOH/g of oil was established for CFC/mineral oil systems based on analysis of 700 used lubricants from operating systems and failed units. There is no consensus within the refrigeration industry as to the critical TAN value for HFC/POE systems, however, the value will be higher than the CFC/mineral oil systems critical TAN value because of the much weaker organic acids produced from POE. A similar study of used POE lubricants should be performed to establish a critical TAN limit for POE systems.

Titrimetric analysis per ASTM procedures is the most commonly used method to determine TAN values in lubricants in the refrigeration industry and other industries dealing with lubricating oils. For field measurements, acid test kits are often used since they provide rapid, semi-quantitative TAN results. Ion chromatography is a useful technique for the analysis of the POE samples since it allows the determination of individual organic acids as well as ionic degradation products.

Alternative acid measuring techniques such as free radical measurement and voltammetry, which are employed in other non-aqueous fields, may also be applicable to refrigeration systems and should be investigated. If successful, these techniques may provide an earlier indication of refrigeration system deterioration than the currently used titrimetric method.