Polarized Refrigerant Oil Additive

Technology for Improving Compressor and Heat Exchanger Efficiency

Abstract

Polarized refrigerant oil additives (PROA) save energy and equipment by increasing the efficiency of heat exchange systems and reducing equipment wear. The technology, especially developed for air-conditioning and refrigeration compressors, forms a boundary film on metal parts and provides lubrication while protecting parts from friction degradation. It forms a microscopic chemical layer on all metal parts without the introduction of solid particles.

About the Technology

Although there are many types of refrigerant oil additives currently on the market, this Federal Technology Alert deals with a specific type of additive, a polarized refrigerant oil additive (PROA), designed to improve the efficiency of heat exchangers in air-conditioners, chillers, heat pumps, and refrigeration systems, in addition to increasing the lubricity of refrigerant oil and reducing wear on compressor parts. Its unique formulation distinguishes it from other oil additives.

This special class of additives contains an activated polar molecule (highly charged at one end). The charged molecule has a strong affinity for metal, and coats metal surfaces in the compressor with an essentially single-molecule thin layer. This layer not only increases the ability of oil to lubricate moving parts in the compressor, but also displaces the build-up of refrigerant oil in condenser and evaporator coils thus improving heat transfer of heat exchangers. It is the build-up inside heat exchanger coils that most reduces the heat transfer ability of the system.

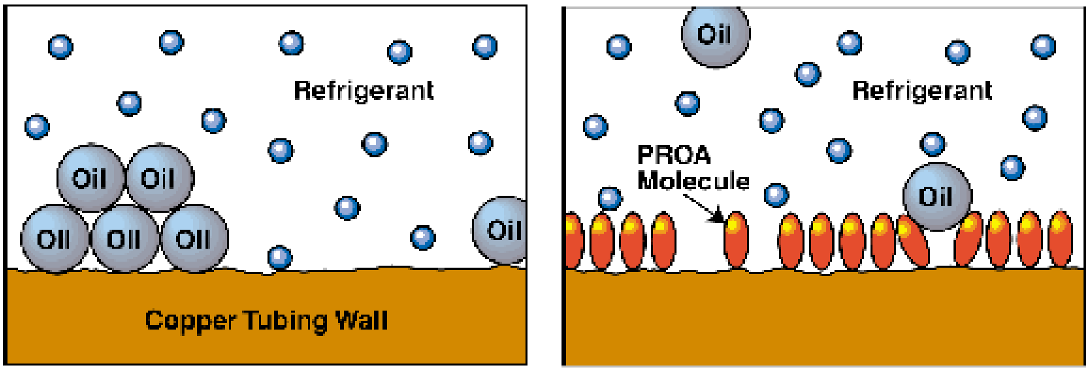
Application Domain

The PROA technology can be safely used to treat air-conditioners, heat pumps, refrigeration units, and freezing equipment in the private and Federal sector. It can be used to treat screw-type compressors, hermetically and semi-hermetically sealed positive displacement (reciprocating) compressors, scroll compressors, and centrifugal chillers. It is not applicable to absorption chillers. The PROA treatment can be applied to all sizes of air-conditioning and refrigeration systems.

Energy-Saving Mechanism

To understand how PROA works, consider briefly the make-up of a heat-exchange system. The cooling action in an air-conditioning or refrigeration system is created through the use of a compressible fluid that moves heat from one location to another. During the process of expanding and condensing, heat is either absorbed or rejected through a copper (or similar metal) coil.
Refrigeration systems also include a lubricant (often called refrigerant oil), which circulates continuously through the compressor to lubricate moving parts. Frequently, oil escapes the compressor area and moves with the refrigerant through the rest of the system. The oil entrained in the refrigerant travels from the compressor to the condenser and evaporator, where it attaches itself to the metal surfaces on the inside of the heat exchanger coils, in effect insulating them .The result is reduced heat transfer ability, which in turn effectively reduces capacity and increases run-time in order to obtain the same

amount of heat transfer.
The addition of PROA to refrigerant oil in the compressor introduces an a-olefin molecule, chlorinated paraffin, (synthetic formula introduced in 1996 contains no chlorinate or paraffin wax) which remains in a liquid state as it moves throughout the system with refrigerant oil. The activated polar molecule in PROA is carried in a non-particular (contains no particles) oil base, which readily mixes with refrigerant oil. Each molecule, possessing a negatively charged region, seeks to attach itself to the metal surfaces throughout the refrigeration system. The molecule displaces other molecules, including dirt, carbon deposits, and oil, eventually forming a thin layer. Because the polar molecules have no affinity for each other, the layer is a single molecule thick. Figure 1 shows a diagram of this process.



Oil layer attached to heat exchanger wall impeding heat transfer.

Activated polar molecule displacing oil molecules facilitating better heat transfer.

Benefits

The two most important benefits of PROA treatment are improved heat transfer in the evaporator and condensing coils and increased lubricity of refrigerant oil. These two important benefits produce several other side benefits:

1) Restored volumetric capacity -- The addition of a stabilized boundary layer on all moving parts improves the seals made between moving parts and reduces the amount of "blow-by," volume lost during compression through bad seals.
2) Reduced run-time -- By improving the heat transfer rate of the evaporator and condenser, the system capacity is affectively increased. With increased capacity, compressors that cycle don't need to run as long to produce the same amount of heat transfer, resulting in energy savings.
3) Reduced mechanical friction -- By coating the metal surfaces of moving parts in the compressor, mechanical friction between the parts is reduced. Improved lubricity reduces corresponding wear on parts and excess heat generated.
4) Extended equipment life -- Reduced mechanical friction, wear on moving parts, and excess heat generated all serve to extend the life of equipment.
5) Quieter operation -- Field experience has shown that PROA treatment often produces a smoother, quieter running system.

Installation

Installing PROA is a simple process, but adherence to a few precautions will greatly facilitate its effectiveness. PROA should always be installed by a licensed professional to avoid any accidental release of refrigerant into the atmosphere.
Pretreatment Inspection. It is recommended that a qualified HVAC technician perform a standard maintenance inspection before any refrigeration system is treated with PROA. This inspection should verify that the following conditions exist:
- Head pressure and suction pressure within design limits

- Adequate refrigerant in the system and absence of oil or refrigerant leakage
- Cleanliness of coils and filters
- Thermostats or control systems functioning properly
- Heat exchanger coil fins free of dust, dirt, and corrosion.

The pretreatment check is important because these conditions all affect the performance of the system. In addition, it is important to ensure proper functioning so as to avoid the expense of re-treatment should the system fail or lose oil or refrigerant before the PROA has dispersed through the system.

PROA Treatment. The amount of PROA to be added is determined by the volume of oil in the compressor. The ratio of PROA to compressor oil is 95% compressor oil and 5% PROA. The easiest way to treat a compressor is to remove 5% of the compressor oil and replace it with the same volume of PROA. It is important that the recommended amount of PROA not be exceeded.

The basic PROA treatment procedure is as follows. First, start the unit and keep it running throughout the installation. Introduce PROA into the unit's cool gas suction line schraeder valve. A charge oil pump designed specifically for the system should be used to decrease the risk of introducing contaminants. It is important that no moisture be allowed to enter the system during this process.

If the system is smaller than 25 tons (88 kW) of cooling, PROA may be introduced in a single treatment. However, if more PROA is required, it is important to use two equal treatments to obtain the 95%-5% mixture.
It is common to see a slight increase in energy consumption immediately following treatment as PROA begins to move throughout the system and oil and other particles are dislodged. Dividing the treatment into smaller doses minimizes this affect.

Post-Treatment. PROA takes one to two weeks of normal operation to disperse completely throughout the system. As the activated polar molecules bond to metal, they displace oil and carbon deposits on tube surfaces. Particularly in older systems, these deposits and oil returning to the compressor may clog in-line filters and driers.

Variations

Introducing the PROA into the oil reservoir in the compressor crankcase is the simplest, but not the only way to introduce the PROA treatment. In hermetically sealed compressors, it is added through the low-pressure port on the refrigerant line. Experience with residential heat pumps with hermetically sealed compressors showed that most require the addition of a tap valve to the low-pressure end of the refrigerant line. PROA is then added using a "Dial-a-Charge" or similar charging cylinder. Whether PROA is added to the refrigerant line or the oil reservoir, the important thing is that the compressor remains free from contamination.

Application

This section addresses the technical aspects of applying PROA treatment. The range of applications and climates in which the technology can best be applied are discussed. The advantages, limitations, and benefits in each application are enumerated. Design and integration considerations for the PROA technology are highlighted, including costs, options, installation details, and utility incentives.

Where to Apply PROA

The technology can be applied in air-conditioners, heat pumps, refrigeration, and freezing equipment. Equipment must be scroll compressors, positive displacement (reciprocating) compressors, screw-type compressors, or centrifugal chillers. PROA is not applicable to absorption chillers. The PROA treatment can be used safely in all sizes of air-conditioning and refrigeration systems. PROA can be used in any system where temperatures range between -65°F (-53.9°C) and 400°F (204.4°C).

PROA is compatible with R-134a, R-124, R-125, and R-22. It is also compatible with refrigerants from the Methane series (R-10 to R-50), the Ethane series (R-110 to R-170), and the Propane series (R-216ca to R-290). It is also compatible with Chlorodifluoromethane (R-502), Sulfur Dioxide (R-764), and Carbon Dioxide (R-744). Consult the manufacturer for information about additional compatibility.

The active ingredient in PROA treatment, the activated polar molecule, is available in a carrier solution of either mineral or synthetic oil. When ordering PROA for a specific refrigeration system, be sure to request the type of carrier oil that is installed in that system.

The PROA treatment is most effective in older compressors. In a newer unit, with good seals and little wear, less oil is drawn into the condenser and heat exchanger. The PROA treatment often shows only a 3% to 7% increase in efficiency. Although newer systems experience a smaller increase in efficiency, the PROA treatment will help to keep them from degrading by preventing build-up on the heat exchangers in the first place.

Technology Performance

The PROA technology is relatively young. Testing of the product occurred during the late 1980s, and the patent was awarded in 1990. Much of the field experience to date has taken place in the private sector, some as early as 1987. No major demonstration has taken place in the Federal sector, although the product has been installed in two U.S. Post Offices. Because air-conditioning systems in the private sector are often identical to those found in the Federal sector, private sector performance evaluations will apply to similar installations in the Federal sector.

Energy Savings

A portion of the energy savings may be due to the O&M maintenance performed prior to treatment with PROA, especially in units with poor maintenance history. Unfortunately, with the data available it is impossible to separate the improvements from proper O&M and the improvements from PROA treatment.

Energy Consumption. PROA is most effective in reducing energy consumption in older compressors. In a new unit, good seals and little wear cause less oil to be drawn into the condenser and heat exchanger. The PROA often shows a 3% to 7% increase in efficiency. However, with units five years old or greater, efficiency can be improved to anywhere from 10-30%. Savings as high as 36% have been reported.

One manufacturer reported 23 demonstration installations where the average (mean) energy savings was 21.2% (standard deviation = 6.3%). Figure 2 shows a histogram of these 23 installations plotted as the percentage savings versus the number of times that savings occurred. With an average of 21.2%, 95% of all the values fall within a confidence interval from 14.8% to 27.5%. The energy savings at these installations were reported by local personnel; therefore, no means exists of establishing accuracy or standardizing the data collection procedure. In only one case was it clear that weather variability (cooling load) during the study period was considered.

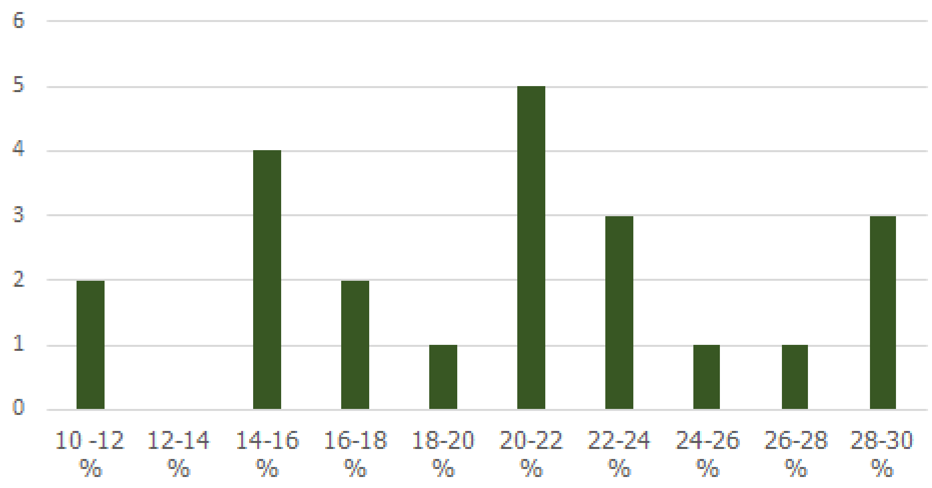


Fig. 2. Energy Savings Reported by Manufacturer

One method of estimating energy savings would be to assume the 23 installations reported by the manufacturer in Figure 2 represent a typical distribution of energy savings. Instead of using the average (mean), 21.2%, to estimate energy savings, use 14.8%, the lower limit of the confidence interval. This is a conservative estimator since 95% of the results will be greater than 14.8%. This is probably a safe approximation for refrigeration systems that are inside a building and have a constant load (e.g., coolers and refrigerators) and for air-conditioning systems in warmer climates (greater than 1000 cooling degree days). 14.8% can be used as an estimator when nothing else about the system is known. However, the following attributes affect energy savings:

- Age. If the compressor is less than five years old, actual savings will be less--often only 3 to 7% for compressors less than 2 years old.

- Size. Theoretically the percentage energy savings should remain the same, regardless of system size; in practice, large central cooling systems are better maintained and controlled more closely. Percent energy savings will therefore be reduced on larger systems.

- Climate. If the air-conditioning system being treated operates in a cooler climate (less than 1000 cooling degree days) where reduced cooling load causes shorter run-time and more cycling, the total savings will also be less and payback periods longer.

Using the installations in Figure 2, all the factors affecting energy savings were analyzed. It was found that the age of the system at the time of PROA treatment is the most important variable in predicting energy savings. Figure 3 shows the 16 systems for which age data were available plotted versus energy savings. The solid line in Figure 3 is the regression line that is the best fit for the data.

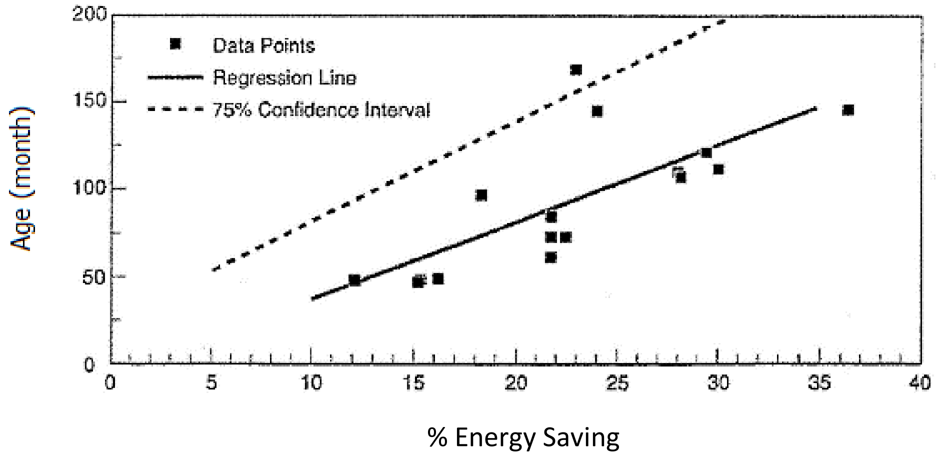


Fig. 3. Compressor Age Versus Energy Savings

Using system age to estimate energy savings is possible by identifying the age of your system on the Y-axis in Figure 3, tracing horizontally to the regression line, tracing vertically to the X-axis, and reading the energy savings. To obtain a conservative estimate, use the dashed line in Figure 3, which represents the upper limit of the 75% confidence interval. The actual savings should be greater than your estimate 75% of the time. Remember, this estimating procedure is imprecise considering the number of other variables affecting energy savings and the small number of data points in this sample.
Electric Demand. In most cases, a reduction in electric demand is realized after PROA treatment. Generally, the highest demand occurs at startup, as the compressor works the hardest to get stationary parts moving. PROA treatment increases lubrication, which reduces the amount of work required to start compressor parts moving.
The best example of reduced demand at startup was experienced at Sonny's Real Pit Bar-B-Q in Tuscaloosa, Alabama. Sonny's two 7.5-ton (26 kW) air-conditioning units were treated with PROA. Figure 4 shows the 15-minute average amperage draw plotted versus time of day for a day before and after PROA treatment that were determined to have identical loading. Peak demand on Sonny's two units was reduced almost 31% following PROA treatment. On a walk-in cooler in South Saint Paul, Minnesota, demand was reduced 2.7% following PROA treatment.

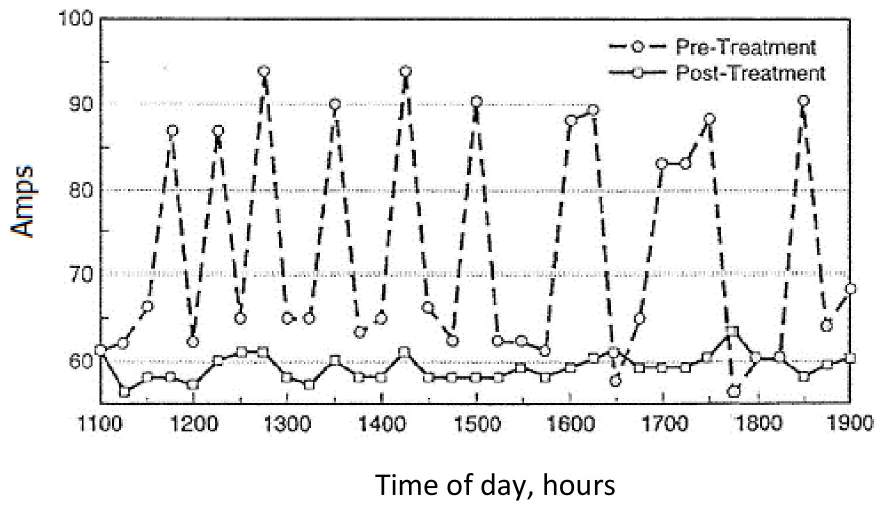


Fig. 4. Reduced Electric Demand at Startup

Like consumption savings, demand savings will vary with each individual system. Unfortunately, estimates of demand reduction are difficult to quantify because of insufficient supporting data. The demand reduction experienced at Sonny's Real Pit Bar-B-Q should not be treated as typical.

Maintenance

PROA is an additive; there are no elements of the technology that require any maintenance per se. However, the treatment using PROA has some effect on the standard maintenance of compressors and refrigeration systems.

Since PROA bonds to the metal surfaces in the system, much of the product remains in the system even if oil is lost or the system is drained. After every third oil change, the system should be treated with 10% of the original amount of PROA to maintain the proper level in the system. Thus, if 10 ounces (284 ml) of PROA were used initially, an oil change should include an additional 1-ounce (28 ml) of PROA.

Other Impacts

PROA takes one to two weeks (during normal operation) to fully spread through the system. As the polar molecules bond to metal, they displace oil, carbon molecules, and dirt on the tube surfaces. Particularly in older systems, these deposits and oil returning to the compressor may clog in-line filters and driers. Several weeks after initial treatment, it is recommended that in-line driers and filters be (differential pressure) checked for accumulated debris that the PROA has displaced from the surfaces inside the compressor and piping.

Case Study

Because it is a relatively new technology, PROA has not had a major demonstration in the Federal sector. The case study described here concerns an application in the private sector and is presented so that the mathematics and data requirements might be better understood. Parallel to the actual case study, additional discussions provide relevance to the Federal sector. This case study should provide a step-by-step process to identify potential energy savings, install PROA, and verify the savings at a Federal facility.

This case study was chosen because it is the most heavily instrumented installation available. Despite the small size of the refrigeration system, the lessons learned can be generalized to systems of all sizes.

PROA Installation

It was determined that the refrigeration system was a good test location for treatment with PROA. It fit all the application parameters as presented in the Applications section of this document. The compressor is a hermetically sealed reciprocating compressor, requiring 1 ounce (28 ml) of PROA treatment.

Savings Potential

An estimate of the actual savings is difficult to make, since performance improvements vary depending on age, type of system, maintenance history, loading, and other parameters. Two procedures for estimating percent energy savings are presented in this Technology Alert. The first uses the data in Figure 2 to approximate the energy savings as 14.8%. The second uses the age of the system and Figure 3 to approximate energy savings. Because we know the age of the system (144 months), we will use the second procedure. The estimated energy savings is 21% using the 75% confidence interval regression line.

The monitored baseline energy consumption was 1155 kWh. If the PROA treatment produces a 21% savings, 242 kWh should be saved over a three-week period with identical cooling load. Assuming the cooling load is constant over the entire year, (b) the estimated annual energy savings is 4,204 kWh

Verification of Energy Savings

After treating a system with PROA, it should be allowed to stabilize as the PROA molecules are dispersed throughout the system. After about 2 weeks, repeat the baseline monitoring procedure to determine post-treatment energy use.

The system in our case study was monitored for four more 3-week periods to see whether efficiency continued to increase. During the last 3-week period, period 5, the system used 878 kWh and had a maximum demand of 3.25 kW. A comparison of periods 1 and 5 indicated that energy consumption was reduced 277 kWh or 24.0% and peak demand was reduced 0.09 kW
or 2.7%.

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