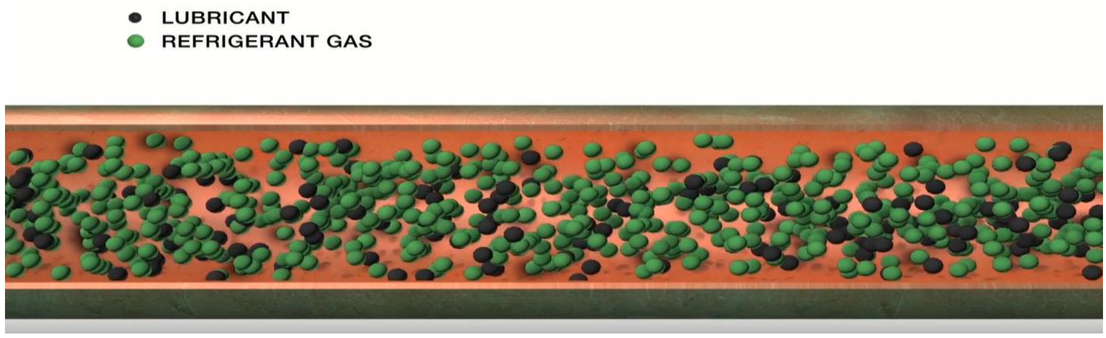
EFFICIENCY THROUGH CHEMISTRY

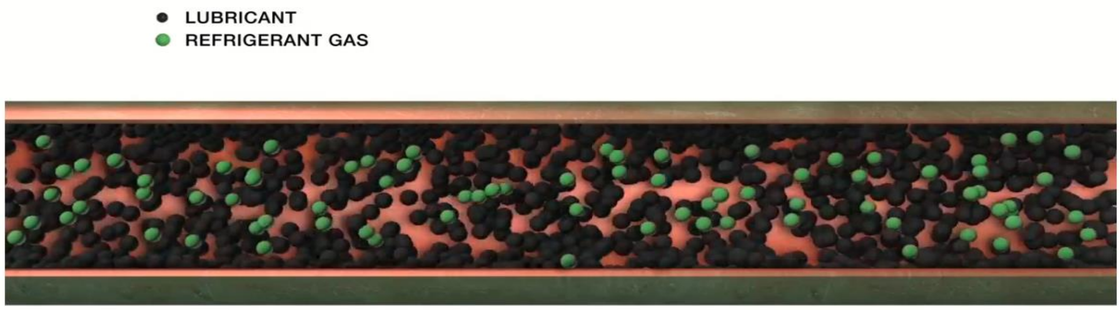
Mattavelli Paolo – Errecom

The world of systems running with refrigerant gases is a concentrate of chemical reactions carried to their edge by chemical and physical conditions that naturally characterize a system. Changes in temperature, high pressure and changes of state, in the presence of highly catalytic metals, are the natural working conditions of the system.

These reactions take place not only in the compressor, where there is a high mechanical effort, but also in lines, valves and particularly in exchangers.

The ratio of miscibility and immiscibility between refrigerant gas and lubricant is different for each combination and it is itself exploited to let the system work properly. Lubricant gets "diluted" by the refrigerant and, depending on solubility, is transported and runs in the system. In the liquid phase there is normally a greater transport of lubricant, with a substantial reduction in solubility after evaporation. This phenomenon tends to leave the heavier fractions to settle, with a considerable and systematic impoverishment of the lubricant. It has been shown that dynamic heat of the refrigerant gas and lubricant particles are the key elements to move lubricant in the gas-phase regions.





Smaller particles require a less dynamic head for transport. In the evaporator, boling action of refrigerant generates inertial forces adequate to create small-diameter particles (50 μm) and the miscibility of the lubricant reduces the surface tension. At very low temperatures and pressures, the lubricant can become immiscible and its viscosity high. This combination can lead to the accumulation of lubricant in the evaporator and / or in suction lines and as a consequence oil won't return easily to the compressor. In liquid and liquid-gas region, miscible lubricants dissolve in refrigerant and are easily transported in disorder with the flow. In presence of a low surface tension and adequate inertial forces, immiscible lubricants can generate an emulsion: in this case the circulation of the lubricant can be satisfactory. However, at low temperatures, the mass flow of the system is minimal and the viscosity is high: This could cause lubricant build-up in low-speed regions.

Oil management in refrigeration systems is widely discussed by ASHRAE in official literature. All refrigerant compressors let a specific amount of oil circulate in the system. Oil separators are used where the excess of lubricant can affect system performances or where reduced oil return conditions exist. Instead, they are rarely used for heat pumps.

While choosing a lubricant, it is necessary to consider its chemical compatibility with the type of refrigerant and the viscosity required for the application.

A further complication occurs in case refrigerant gas is composed by a mixture and individual components of refrigerants could have different solubility in lubricant; that could giving rise to the fractionation in the system, different from the conditions of vapor-liquid balance in the absence of a lubricant.

Lubricants that have limited miscibility and lubricants that have a high viscosity could have a potentially negative impact on both operating cycle parameters, the duration and general performances of the system.

The component of lubricant that deposit in the system together with removing lubricating material coming from the compressor, create a barrier that generates significant damage to the circuit:

1) The heat exchange reduced with performance losses of 30% that rise up to 40% in systems with more than 20 years.

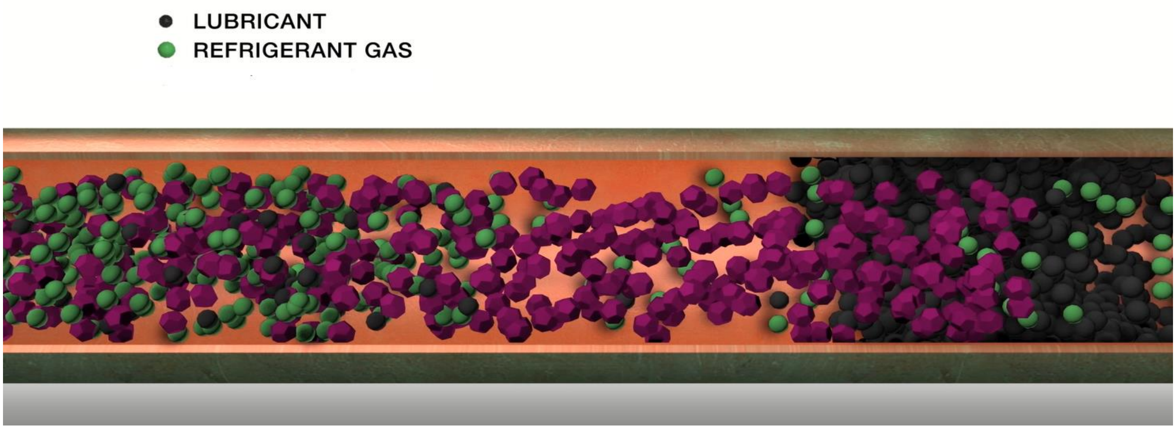
2) The diameter of the channels is reduced with consequent changes in flow inside the system.

3) The deposited lubricant is a point of accumulation and action for humidity, acidity and radicals.

<u>The deposit of the lubricant therefore decreases the performance of the system, increases energy consumption, helps corrosion and the reactivity of its components with consequent breakages.</u>

The study of our laboratory was oriented towards the development of additives aimed at blocking chemical reactions (elimination of moisture, acidity and stabilization of the corrosive and oxidative activity of the system) and the removal of lubricant deposits present in the system.

While in the past it was operated by inject low viscosity lubricants to give an apparent increase in performance, with the consequence of destroying the viscosity of the compressor lubricant and compromising the system, today we operate through additives that favor the return of heavy fractions back into circulation. We use molecules with a polar head, a lipophilic body and a highly "disordered" geometry that are positioned between the lubricant and the metal, breaking the geometries of the deposits and freeing their circulation.



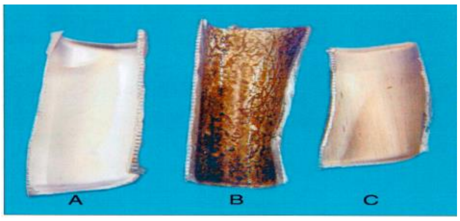
The tests carried out over the last 10 years on systems containing POE, PAG, Alkylbenzeni and mineral oils with different refrigerant gases have given excellent results.

Systems that have lost 80% of their heat exchange capacity, 30% of their efficiency and with a current consumption increased by 20%, after injection, showed (average of the various configurations):

- 73% recovery of heat exchange capacity
- 20% recovery of their performance
- Restoring normal power consumption
- Lowering of the ventilated air temperature by 4°C
- Reduction of compressor vibrations and noise
- Lowering of the compressor operating temperature

This result was obtained through an average addition of 5% on the quantity of lubricant for the old generation molecules and an additive of only 0.7% for those of the new generation called "Ultra". After the insertion of this range of additives, performance losses in the systems over the next 10 years of observation were no longer observed.

We have been compared twin systems, with 5 years of activity and a performance that was clearly compromised. The treated system has started to have an adequate efficiency and electricity absorption. Once the systems were opened, it was observed at different points that the lines and exchangers of the treated system are cleaner, compared to the quantity of deposits found in the untreated one.



A: New evaporator tube
B: Untreated evaporator tube after 400 hours of operation.
C: Evaporator tube treated with additive after 400 hours of operation.

It has also been observed that the use of bigger percentages of additive does not compromise the performance of the system (within the capacity limits of the compressor). Likewise, it has no ameliorative feedback. Therefore, it was deduced that the action of this family of molecules does not generate a direct increase in performance, but the latter is linked to the removal of harmful effects from the system. Once the additive is in action it preserves the system for a long time.

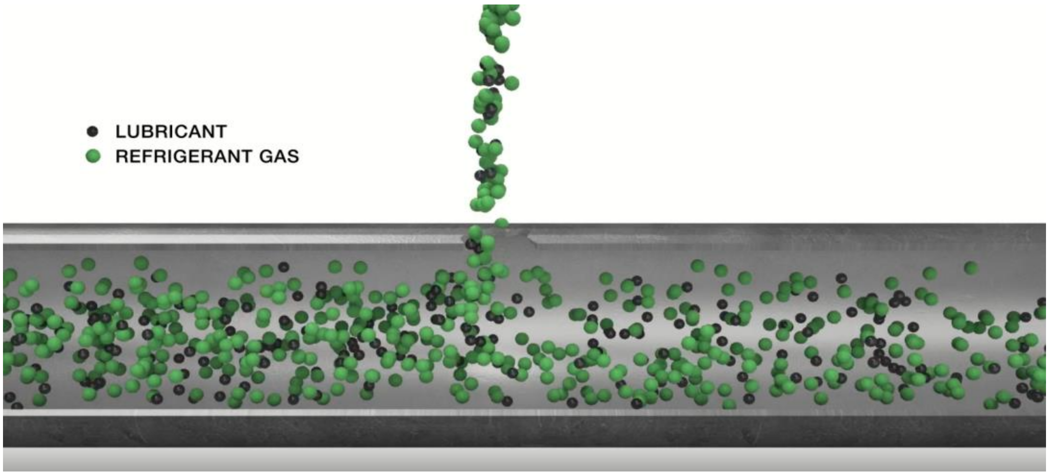
A better behavior and less wear of the compressor was also found as the molecules bind to the metal surfaces increasing their protection.

Furthermore, the incidence of corrosive attacks from the inside, due to acids and oxidative derivatives of the decay of lubricants and gases, are reduced. This result is due in part to the presence of antioxidants in the mixture itself but, mainly, to the removal of those deposit areas that are the "incubator" of the internal reactivity of the system.

Currently more than 300,000 air conditioning, refrigeration and automotive systems are successfully using these additives worldwide.

One of the most visible effects of the deposit of lubricant, its acidification and aggression to metal surfaces is certainly the formation of corrosion and consequent leakages of the system. While medium to large leaks can be easily identified and repaired, widespread or small leaks, caused for example by widespread corrosion, are mechanically undetectable and therefore not repairable. The consequence is a constant dispersion of refrigerant gas which reduces and compromises the performance of the system, producing at the same time a serious pollution of the environment and an increase in the costs of managing the system itself (especially given the growing costs of modern refrigerants).

In addition to common sense, the law requires to act to exclude leakages from the system, drawing on all existing technologies.



There have been additives that repair leaks from the inside for decades.

The first technologies involved the use of reactive polymers with oxygen and/or moisture. This technology was very efficient but generated problems related to reactivity, not only on the surface of the system, but also inside it, causing serious damage and destroying the system.

Modern technologies, on the other hand, are based on the use of micelles, solvated from the lubricant and gases of carbonic origin (CO2, Alkanes or chlorine-fluorine derivatives). These molecules do not operate by chemical reactivity but go to settle in the cracks. Near the surface they tend to lose their solvents which have a higher evaporation rate than theirs. The loss of the constituents that cover them, refrigerants and lubricants, favors the new aggregation that forms an elastic and permanent occlusion.

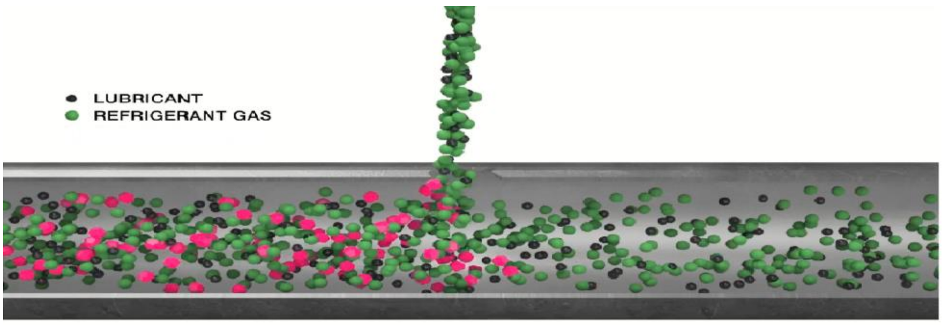
This technology, slower than the polymeric one, has undoubted advantages:

1) No reactivity inside the system: it avoids blocking the expansion valve or dehydrating filters, which instead were places of great reactivity for the polymeric ancestors.
2) Continuous action in the system until the lubricant is replaced.
3) Reduction of the aggressiveness of the lubricant on the system components.
4) Increased lubricant capacity of the lubricant itself with consequent reduction of compressor noise.

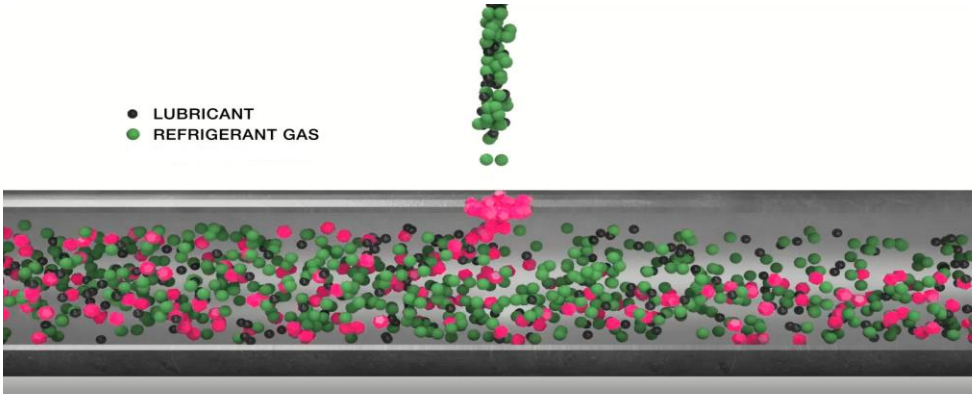
The micro leaks on the various systems tested have been ascertained through the evidence of the refrigerant gas charge drop and have been defined as "micro" through the vacuum test.

This test consists of pushing a system for 5 minutes into a vacuum which is certain of a leak. If, despite the loss, the vacuum is maintained, the leak is called micro.

Once it is established that the leak is micro, leak-stop technology is inserted in a quantity equal to 6% of the lubricant volume or, with a recent Ultra technology, equal to 0.8% of the lubricant. Insertion can be performed with the system unloaded or with the system loaded, through the low pressure valve. Once the system is loaded (if unloaded), it is activated, for an approximate time of 20 minutes for small system, or one hour for large system. After this time the leaks are sealed.

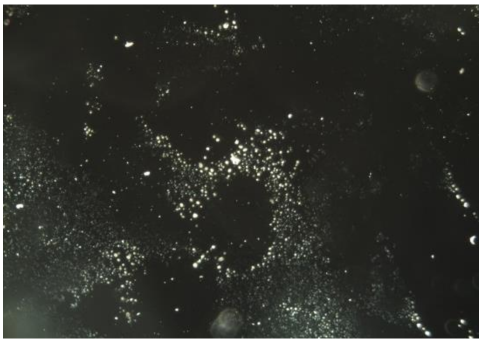


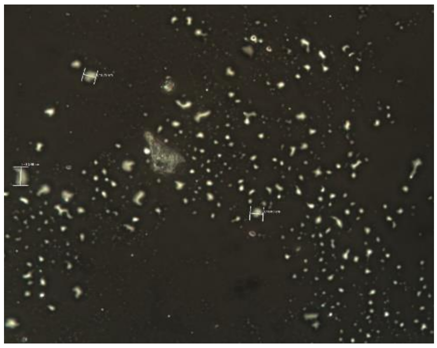
This test was successful on all refrigerant combinations (except ammonia), and POE, PAG AlkylBenzene and Mineral tested lubricant. The reference systems have exceeded 10,000 hours without any more leaks.



The inclusion of this type of product has not changed the electricity absorption nor has it changed the functional capacity of the system.

In the last 10 years this technology, in its variants, has been included in a million systems with a positive result recorded, greater than 97% (in which also systems with larger losses must be estimated).

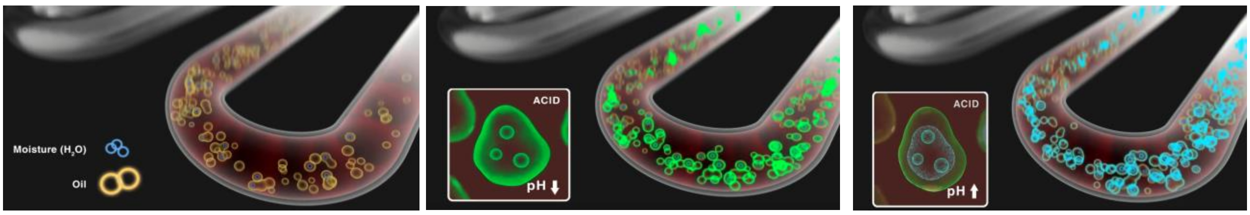




The dispersed particles must have a known dimension, which is constantly monitored and allows the exploitation of metal imperfections.

None of the systems in use have suffered performance losses or functional damage, proving that, to date, non-polymeric chemical intervention is the most efficient viable solution for micro-leak repair.

The maximum efficiency of these operations is achieved by simultaneously operating other additives to control humidity, acidity and oxidative aggressiveness with a dedicated additive.



All these additives are derived from the technologies for developing synthetic lubricants currently on the market.

In conclusion, supporting nowadays that nothing must be inserted in the system outside of refrigerant and lubricant, it has lost all reason.