Refrigeration and Air Conditioning Controls

Filter driers for HFC refrigerants

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Water and acid adsorbing properties of the filter driers play an essential role in the modern refrigeration systems, as they did for the systems of the time before. In addition, there have been added demands for a range of new properties, which have an essential importance for the right choice of filter driers, e.g dirt filtration, compatibility with HFC refrigerants and polyolester oils, and compatibility with several additives as well.

These problems are described in this article.
Finally, the importance of a correct dimensioning of the filter drier is explained and illustrated by the different capacity statements that exist for filter driers.

1. Function

In refrigeration plants and a/c units with hydrofluorcarbons (HFC) as refrigerant, the primary role of the filter drier is to adsorb moisture immediately after the refrigeration plant is put into service. When moisture has been adsorbed, the filter should be exchanged. In this way only, the moisture is removed from the refrigeration system and the risk caused by acid formation can be eliminated.

Thus, the most important demand on the first filter drier to be mounted into the refrigeration plant is a high water adsorption capacity. Additional demand on the second filter to be mounted is acid adsorption.

Why that?

Today there is much attention to keep the several components that form part of the refrigeration plant very dry during building-up. This is due to the fact that the hygroscopic properties of the polyolester oils (POE) and, to a large extent, the corrosive and decomposing properties of the water is brought into focus.
The fear for earlier time's ice formation in the expansion valves and capillary tubes in CFC systems has receded into the background. Ice formations hardly occure, as HFC refrigerants and POE oils are able to dissolve water to a degree that possibly freezing free water will not occure.

As very dry refrigeration system is required, the demand on the filter drier to be mounted for the first time in a refrigeration plant or an a/c unit is a <u>very high water adsorption capacity</u>. The filter drier must be able to adsorb the initial moisture added to the system during building-up and which is not removed during a possible evacuation. In this way the risk of a later acid formation is reduced. However, free water is a condition that the acid hydrogen, generated by extremely thermal (high temperatures) or mechanical (frictions, metal against metal) influences of oil and refrigerant, becomes aggresive.

Aggresive acid attacks metal surfaces which begin to corrode. It also reduces the insulating properties of the motor windings with risk of spark formation and motor damage of hermetic or semi-hermetic compressors.

When changing the initial filter drier, e.g. after 60 days of operation, the demand on the new filter drier is not only to adsorb water but also <u>acid</u>. The requirements on the water adsorption capacity will be reduced, as today's plant is constructed with very tight joints. Consequently, the quantity of moisture added during operation will be minimum. On the other hand, the filter drier must in the long term be able to prevent from damages by acids. It must be capable of adsorbing or neutralizing acids.
This requires that the filter drier core consists of two or more desiccants.

The reasonable choice of filter drier number one is a filter drier with a core consisting of pure molecular sieves (MS).
This desiccant has high affinity towards adsorption of water in media, where the moisture content is very low in relation to the total, theoretically soluble quantity. In quite new systems there is no acid so that this property should not be required from filter number one, in case the change of this filter drier is planned.

The reasonable choice of filter drier number two is a filter drier with a combination core, consisting of both molecular sieves and activated aluminia. The characteristic of activated aluminia is that it <u>adsorbs</u> the organic acid generated by thermal decomposition of oil and it neutralizes the inorganic acid generated by thermal decomposition of refrigerants.

This filter drier type will in future be the standard filter drier in the refrigeration plant.

2. Criteria for choice of filter driers

In addition to moisture and acid adsorbing properties, the filter drier for modern refrigeration systems should meet demands for following properties:

- *High reaction rate.*
- *Good dirt filtration properties.*
- *Compatibility with HFC refrigerants and POE oils, with or without additives.*

Let us have a look what is hidden behind these criteria.

Reaction rate

For the manufacturer of a refrigeration unit it is of decisive importance that the filter drier quickly desiccates the refrigeration system.
Thus, the running-in time is shortened and the finished refrigeration system can quickly be delivered. The running-in time is normally determined by the moisture indicator of the sight glass.Thus, the charging process is assumed to be satisfactorily performed, when the indicator changes from wet (yellow) to dry (green) after a normal running-in period has elapsed.

Requirements for high reaction rate make demands on the filter drier manufacturer as to the choice of the type of molecular sieves and the binder for the core. Thus, for instance, are certain types of molecular sieves used for loose charge 10 times or more slower with regard to reaction rate than molecular sieves used for cores. This is due to the requirements for highly abrasive resistance of the surface of molecular sieves beads intended for loose or compressed charge. Thus, access to the cavities in the molecular sieves is more difficult and the reaction rate is falling due to the surface coating.

Dirt filtration
As a consequence of the molecules' polar construction, both POE oils and to some extent also HFC refrigerants act as solvents with an intensive cleaning effect. This causes dirt particles formed during operation, e.g. abrasion particles, not to settle, but on the contrary they are held floating and permanently transported through the refrigeration system.
Correspondingly, dirt particles which earlier settled, e.g. inside a copper tube, evaporators and condensers, are set free.
To prevent these particles from being lead into the compressor, it is necessary that a certain amount can be collected in the filter drier.

Out of considerations for components like valves or specially dirt-sensitive applications like liquid injections in the suction gas, it is necessary that dirt particles larger than 20 μm are retained.

These two requirements - high dirt capacity and great filtration properties - challenge to a large extent the filter drier manufacturer, as these requirements to a great extent technically counteract each other.

For many users it has become a matter of practice to install a filter in the suction line in accordance with ASERCOM's[1)] instructions. This filter can advantageously be used in systems with HFCs, where it is a low-price supplementary protection of the compressor.

The figure below illustrates the distribution of particles in the refrigerant that passes through a Danfoss filter drier, type DN. Characteristic of the curve is that up to 95 % of dirt particles even smaller than 20μm are retained.

Compatibility
With compatibility tests it is examined whether refrigerant, desiccant and POE oil react with each other so that chemical or physical decomposition of one or more components occurs. Additionally, it is tested whether the core keeps its strength and whether the other elements in the filter drier, e.g. the filtering element are fully resistant.

The chemical and physical compatibility tests are carried out among other things by means of sealed tube steel containers, in which the mentioned components are exposed in 90 days and nigths at 65°C and 120°C.
Before and after the tests, a gas chromatogramme of the refrigerant is taken. This describes the kind of substances and the amount hereof in the refrigerant. If there is no difference between the chromatogrammes it is a sign of compatibility.

An element analysis and/or X-ray diffractogramme is taken of the pure desiccants. By this it is examined whether the crystalline structure of the desiccant changes. A change would indicate that substances present in the refrigerant or new substances generated during the exposition attack the desiccant. If this happens, it is a sign that compatibility is unsatisfactory.

In addition to these tests the strength of the cores is checked as well as the water adsorption capacity of the desiccants. Both tests are made before and after the exposition in the steel containers.

If additives are used in the oil, it is recommended that problems in connection with compatibility are solved together with the oil supplyer and/or filter drier manufacturer. Additives are added to make the oil more effective and to yield some desirable properties.

The following additve types might be used:
- *antioxidants*
- *viscosity modifyers*
  viscosity/ temperature
  viscosity/ pressure
- *corrosion inhibitors*
- *improvement of the oil's wearing properties*
- *antifoam agents*
- *bacteriostatic*

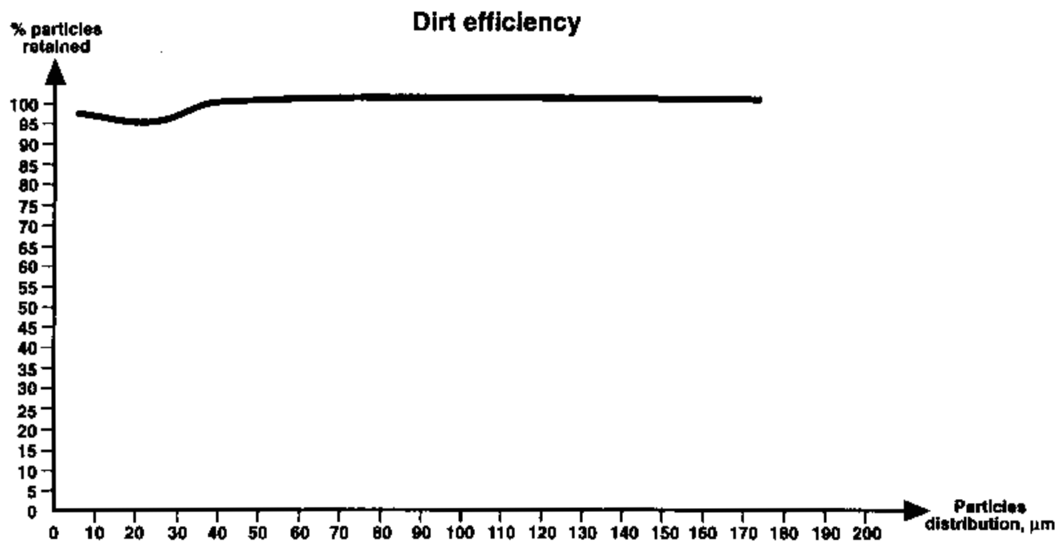

Fig. 1

When using additives in oil, it is necessary that the filter driers neither adorbs nor chemically reacts with the additives.
Especially important is to be cautious when using polar adsorption additives. These are intended to be adsorbed on bearings and similar stressed surfaces in compressors.
However, their molecule size and polarity makes that they can be adsorbed by certain desiccants. See fig. 2.

The use of additives will in future most likely be increased. This is assumed, as the refrigerants to replace R 502 and R 22 operate at higher pressure. Consequently, they will much more stress the movable parts of the compressor, even if POE oils (because of their polar molecule structure) to a larger extent than mineral oils are adsorbed on metal surfaces. Here they form a relatively strong oil film. Thus, wear as a consequence of metallic contact in bearings or the like, will be less probable, if the conditions for that matter were identical. But they are not!

Due to this fact, additives will obviously become a topic towards which filter drier manufacturers in future must pay more attention.

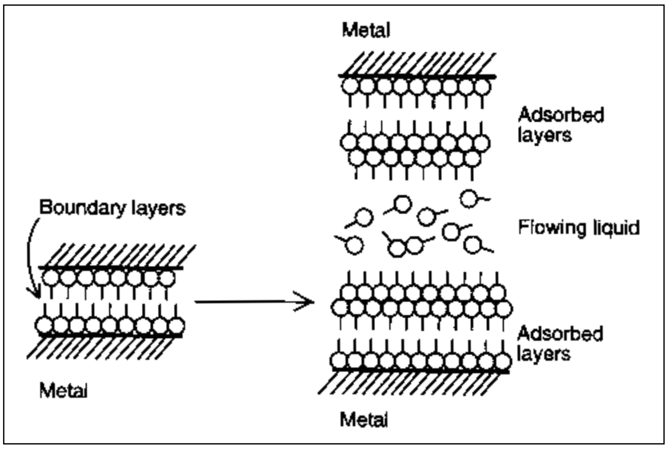

Fig. 2: Model of J. Burstin, considering free flowing molecules during the process of starting.

3. Dimensioning

In connection with questions on dimensioning of filter driers, some uncertainty can often be noticed. The uncertainty is due to two conditions: Partly uncertainty concerning use of the several capacity statements available in data sheets and partly the filter drier manufacturers' different opinions of how to state or use the capacities.
Here, circumstances will be pinpointed which the author thinks are of primary importance for the correct dimensioning of filter driers.

For the dimensioning of filter driers, normally three capacity types are available for the manufacturer:

- *Flow capacity*
- *Water adsorption capacity*
- *Recommended plant capacity*

Let us see what is hidden behind these terms.

Flow capacity

The flow capacity is based on a liquid flow. The reference is given in ARI standard 710.86 which prescribes that the flow capacity must be stated in m^3/h or in kW.
As standard reference $t_e = -15°C$, $t_c = +30°C$ and a pressure drop in the filter at 1 psi (0.07 bar).

Advantages of using this capacity:
- *Capacity statements related to an international standard*
- *Security for that the pressure drop in a new clean filter drier is within acceptable limits*

Disadvantages in using this capacity:
- *Different filter drier sizes end up with identical capacity statements. This is due to the fact that the connections are decisive for the largest contribution to the pressure drop in the filter drier.*
- *No evaluation whether the filter has sufficient water adsorption capacity.*
- *Some manufacturers still state the capacity at a pressure drop by 2 psi applied until 1980.*

Further this capacity statement cannot stand allon but is an absolute necessary parameter in connections with dimensioning.

Water adsorption capacity

States which water quantity the filter drier is able to adsorb and to retain under defined conditions of equilibrium (EPD) between refrigerant and desiccant. The reference is ARI 710.86.

Defined as the amount of refrigerant the filter drier is able to dry, if the water content in the refrigerant under starting and final conditions, corresponds to the conditions determined by ARI.

Can be stated in *kg refrigerant*, *gram water* or *water droplets*. It is assumed that 20 droplets = 1 gram water. Danfoss prefers to state the capacity in kg refrigerant.

Advantages are:
- *When choosing the filter, it is not necessary to consider how much moisture is in the refrigeration plant.*
- *No risk for underdimensioning with regard to water adsorption capacity. The method ensures agenerously dimensioned filter drier as recommended by ASERCOM[1)].*
- *In cooperation with the filter drier manufacturer, this method can be used for calculation of the final EPD in the refrigeration system, when choosing a filter drier and the starting conditions are known.*

Disadvantages by stating capacity in kg refrigerant:
- *Quite rarely used.*
- *Amount of charge in the refrigeration system must be known or must be estimated.*

Recommended plant capacity
This is the most popular capacity statement. Recommended plant capacities are usually stated for three plant categories; usually refrigeration and freezing plant, a/c plant and factory made units.

There is no standard for this capacity statement which determines the references, i.e. the individual filter drier manufacturer can state capacity data without issuing reference conditions.

As reference, Danfoss uses the flow capacity at a pressure drop in the filter drier of 2 psi (0.14 bar) and the following evaporating and condensing temperatures:

	t_e	t_c	f_h
Refrigeration and freezing plant	–15°C	+30°C	0.25
A/C plant	–5°C	+45°C	0.5
Units	+5°C	+45°C	0.75

Factor f_h considers the expected moisture content and thus implicitly also the amount of refrigerant.Thus, it is for instance assumed that the moisture content in factory made units is three times lower than in refrigeration systems with similar cooling effect built up at the customer's.

Advantages in using this capacity:
- *Quick in operation*

Disadvantages in using this capacity:
- *Inaccuracy.*
- *The amount refrigerant in the refrigeration plant is not taken into account.*
- *Lack of published references.*
- *Different filter drier sizes ending up in equal capacity statements. (See previous flow capacity).*

Therefore, it is advised not to use recommended plant capacity as a primary dimensioning parameter.

Dimensioning example:
The method described in this example, where data for water adsorption capacity and flow capacity are combined, can be generally used. However, if the initial moisture is very small or the filter drier is changed after commisioning of the refrigeration system, a smaller filter size can, of course, be chosen.

a. Amount of charge *10 kg HFC 134a at t_e = 52°C*

To dry 10 kg HFC 134a from 1050 ppm to 75 ppm moisture, a 08 in^3 filter drier is necessary.

b. Cooling capacity *Q_e = 20 kW*

To obtain a mass flow corresponding to 20 kW cooling effect at a pressure drop of approx. 0.07 bar, 10 mm or more connections must be chosen in accordance with the liquid line dimension.

c. Result

For instance, a Danfoss filter type DN 083 is chosen.

4. Conclusion
The development of the new refrigerants, which is far from being ended, was and is a great challenge for the manufacturer of filter driers. From being a shelf product, the most important parameter of which was the price, today's filter driers have become a product which to a great extent are produced based on comprehensive know-how.

The filter drier manufacturer needs a profound knowledge of the chemistry in the refrigeration systems, of the molecular physics and adsorption theory, of the flow theory etc. Only in that way it will be possible to market filter driers based on trust to the manufacturer's know-how. However, it is important to bear in mind the fact that to what extent the right choice of filter has been made will not be proved before long-term use. If the choice was wrong, it might become an expensive affair.

As one of the latest innovations, some manufacturers offer filter driers for ammonia. This is due to requirements that will increase concurrently with the use of NH_3 in small ammonia refrigeration plants with direct expansion, and which originated partly in requirements for optimizing of operating conditions and partly in the expected spreading of polyglycol oils. Oils that are miscible with NH_3, but very hygroscopic - unfortunately much more hygroscopic than POE oils.

Because water decomposes all kinds of oil, reduces their lubricating properties and the COP factor of the plant - conditions which increase the need of service and reduce the plant efficiency - the filter driers will in future be a must for these systems. However, as a water molecule and an ammonia molecule as to adsorption are alike, both with regard to size and polarity, how should the desiccants be able to select water from ammonia? And how can ammonia be prevented from decomposing the desiccants?
This exciting subject must be discussed to another time.

[1] ASERCOM: Association of European Refrigeration Compressor Manufacturers.

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