

Advances in Supermarket Refrigeration Leak Reduction

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Abstract

Commercial refrigeration systems for supermarket applications suffer the reputation of producing relatively high refrigerant losses during their use phase. Rationale for these high losses was seen in imperfect connections during field assembly as opposed to more accurate welding and brazing in a factory environment. Large distributed systems, insufficient performance of commercially available leak detection methods and limited accessibility of pipe work are further reasons that lead to the wide spread belief that DX supermarket refrigeration systems have and always will produce substantial double digit leakage rates on an annual basis.

Forthcoming European legislation will focus on emission reduction through better containment, emission monitoring and reporting as these measures have already been very successful in some EU member states.

This paper looks at selected European areas and investigates into recent developments and success stories in the area refrigerant containment. The paper highlights technical design aspects that contribute to improvements of containment while reflecting current and future legislative aspects. "Do's" and "Don'ts" are pointed out with results from the field complementing the work.

Introduction

Commercial refrigeration systems -with supermarket refrigeration units representing an integral part of this segment- are a key element of the modern cold chain that contributes substantially to today's quality of life. There can be no doubt that there is a very strong social responsibility to maintain the cost effectiveness of this element while ensuring optimum ecological performance. Commercial refrigeration is important. It must be accessible and affordable.

Supermarket refrigeration systems do however have the reputation to suffer from substantial refrigerant leaks. Today's standard system in Europe is a direct expansion unit operating on either R404A or R507 in both low in mid temperature range and to a lesser extent R134a units in the mid temp section with R404A / R507 units complementing the low temperature side. The compressor packs are located in machinery rooms, the refrigerant is condensed in an outside air-cooled condenser and liquid lines feed the numerous cabinets that have a refrigeration demand. High leak rates of these systems are usually attributed to the fact, that they have long pipe runs and numerous connectors and fittings.

In order to improve the environmental performance of supermarket refrigeration units, investigations have focused on alternate system design leading for example to indirect units where a secondary fluid (usually a liquid) is pumped through the sales area to refrigerate the cabinets. CO₂ units with a wide variety of different design approaches are also being evaluated. Looking at those markets where the different technology options compete on equal economical terms none of these alternatives has succeeded in providing a cost effective and reliable alternative.

As opposed to look into new technologies it might be more productive to improve on the existing ones. With respect to the system in question this paper specifically looks at refrigerant losses through leaks.

European Supermarkets

Business Specifics

Before looking at sources of leaks and ways to prevent or minimize them it is surely worth while to look at different European countries and their respective standard supermarkets. Types and sizes of supermarkets vary significantly within Europe and even more so on a world wide basis. Retail strategies and preferred ways to sell differ. “Freezer shops” –a store that almost exclusively sells frozen food – are popular in the UK while being unknown in Germany. In Germany on the other hand medium sized “hard discounters” – markets that offer a “no frills” shopping experience at rock bottom prices – are extremely popular (medium sized refers to the sales area of an individual shop – not the size of the company). They are expanding their market share to other regions while in some European countries (e.g. Italy) this type of food retail appears to be less successful than in others. The French “hypermarché” is relatively close to the typical American approach and offers very large sales areas in suburb locations with easy road access and ample parking space. France has the largest average sales area for supermarkets within Europe. Refrigerant charges in these types of supermarkets can be several tonnes with total refrigerating capacities approaching or even exceeding MW ranges.

Figure 1 depicts the average sales area of supermarkets in selected countries.

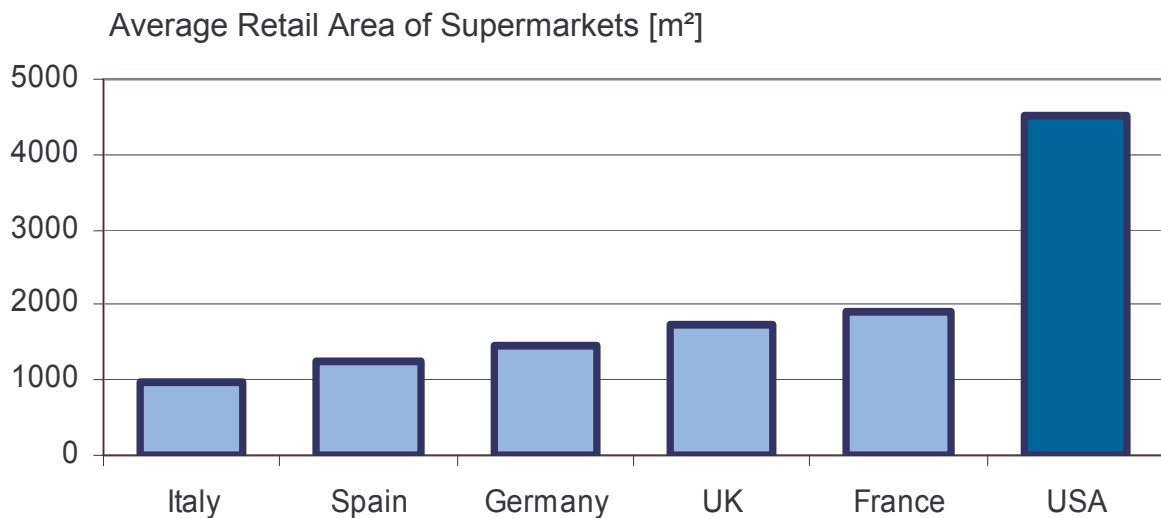


Figure 1: Average Retail Area of Supermarkets in selected countries

With larger retail spaces the installed refrigeration capacity obviously increases. Larger systems have higher refrigerant charges and therefore a higher potential for refrigerant losses.

Refrigeration Specifics

Not only do sizes and sales strategy vary from region to region. When looking at system designs there are also differences and regional issues. This is a consequence of different companies maintaining market leaderships in different regions but it also has to do with historical reasons and maybe even climate specifics.

European supermarket refrigeration systems were the first to be converted to HFC refrigerants. Large parts of the US industry moved to R22 when R502 was phased out. This decision was

largely cost driven as the price for low temperature HFC refrigerants (R507/R404A) can be more than three times higher than that of R22. Lack of extensive field practice was another reason for the decision taken at that time. With higher refrigerant prices the minimization of refrigerant losses is obviously prioritized.

While installing and servicing of supermarket refrigeration systems is carried out by local contracting firms the large supermarket chains mostly employ departments that maintain a design control and that dictate the system types. Whether R404A is used exclusively, whether R134a is used in medium temp sections or whether R507 systems are installed will vary from supermarket chain to supermarket chain but usually not from store to store (all systems mentioned are common in Europe).

A typical and conventional way to assemble multiplex refrigeration units in the US is depicted in figure 2 where it is compared to an alternative approach. The conventional design feeds a header with liquid refrigerant from where numerous liquid lines are connected to the display cases, chest freezers and so on. From the cabinets individual suction line are again collected in a header. The alternative approach - called low charge multiplex for the sake of differentiation - works without headers and with single liquid and suction lines. By this means the length of pipe-work, the number fittings and the refrigerant charge are all substantially reduced. The drawback is a need for more complicated control systems when compared to the header solution.

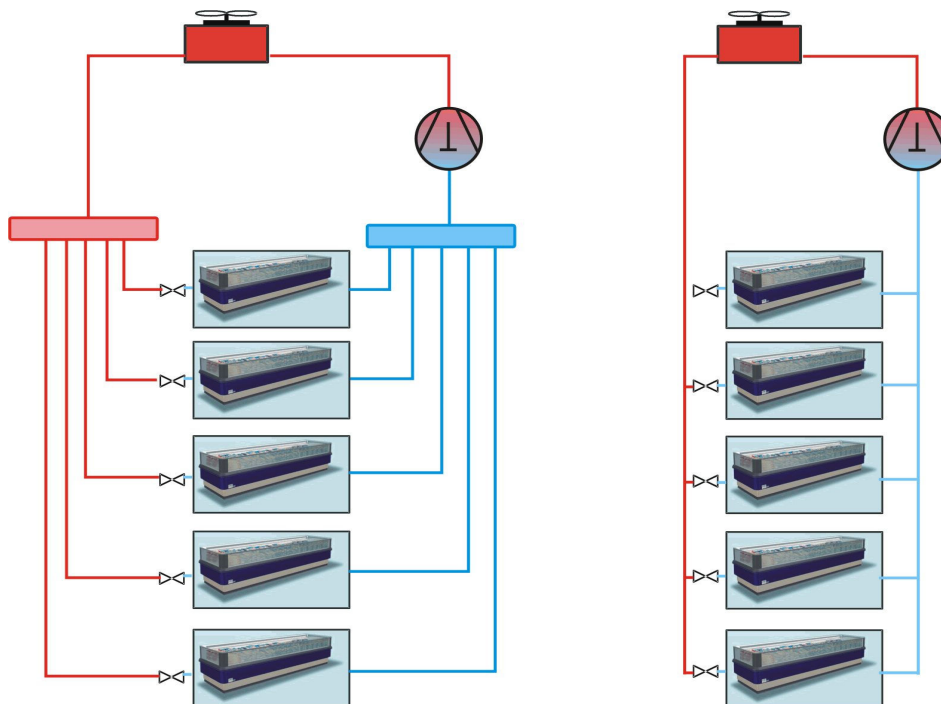


Figure 2: Conventional vs. low charge multiplex systems

The low charge system not only reduces the charge, it also reduces the number of connectors which are today highlighted as the major source for refrigerant losses. Mechanical connections (e.g. flared joints) are typically inferior to metallurgical connections (brazed joints) which appear the choice of the future - obviously with the drawback of decreased serviceability. Both solutions however - and this is important to stress - can be technically tight when applied by skilled and trained personnel but they can both also be fault-prone when not installed professionally.

Important progress has also been made in the area of leak detection methods. The first generation of field assembly leak detectors for HFC refrigerants were not very effective as the

sensitivity of the detection method was insufficient. With the equipment available today these problems appear to be resolved [1]. Modern systems are able to detect of leak rates below 5g/year. Ensuring continuous accuracy and performance of these detectors requires know-how, training and regular service (calibration).

Another very important design criteria is the accessibility of the system with all associated refrigerant containing parts. Covering pipe work with cement screed under floors or plaster behind walls was a very common way to install refrigeration systems. Once covered a potential leak will never be detected. General policies of supermarket chains to have full accessibility of all refrigerant pipework are highly recommended and now more wide spread.

European Legislation and Standardisation

Standardisation

EN 378 [2] must be regarded as the central European standard with respect to strategic reduction of refrigerant leaks. While various product standard do address refrigerant leaks or detection methods it is in EN378 where industry wide requirements are being formulated that have emission reduction as their target. It is important to point out that standards are not legally binding – standardization works with voluntary principles and market mechanisms.

Among the requirements for leak minimization provided in EN are the following:

- For pipework with diameters between 9 and 19mm flared joints shall not be used.
- Flared joints shall not be used to connect thermostatic expansion vales.
- A log book, containing refrigerant consumption and inspection intervals (amongst others) shall be kept by the operating party.
- Detachable joints (e.g. screwed or flared) shall remain readily accessible at all times.

EN 378 is currently updated and the forthcoming version will contain even more detailed requirements with respect to minimization of refrigerant losses.

Legislation

The Dutch regulation on leak free refrigeration equipment from 1994 [3] – often referred to as the STEK regulation – was and remains to be a forerunner in legislative action towards minimization of refrigerant leaks. Among the requirements in this regulation are the following:

- Flared joints shall not be used.
- Pipes shall be joined by welded or brazed joints.
- Design criteria for relief and safety valves (usually blowing off to the low pressure side of the system)
- Systems with a charge of more than 300kg shall be located in a special machinery (at least the compressor racks).
- Systems with a charge of >3kg shall be inspected annually.
- Systems with a charge of >1000kg shall be under constant supervision.
- Logbooks must be kept for all systems with a charge exceeding 3 kg.
- Refill or top up is only permitted if the leak is identified and repaired.

The actual list of requirements is more extensive. On a European level the forthcoming F-GAS regulation is expected to adopt large parts of the STEK principles as this has proven to be very successful which is shown later in this work.

The European approach however is expected to differ in some parts such as mandatory inspection intervals. The currently available draft version prescribes half-annual inspections for systems with a charge of more than 3kg and inspections every 3 months for systems with more than 300kg. Installation of fixed leak detection methods will provide opportunities to reduce the frequencies. How such fixed installations are expected to be designed remains unresolved. The paper at this point is in a draft status.

Emission Results from the Field

In [1] a survey and long term analysis of 62 supermarkets with respect to their refrigerant losses was carried out. The systems were small to medium sized with charges of 10kg to 360kg. In addition to quantifying refrigerant losses, the study looked at location and severity of leaks in order to provide proposals for optimization. One of the most striking results from the study was the fact that 15% of the leaks were responsible for 85% of the lost refrigerant on a weight basis. This teaches that the majority of refrigerant is lost through big leaks. Big leaks are easy to detect. Though continued research into improved leak detection technology is very important it seems from this result that the industry might be able to make a big step with reasonably straight forward changes in their working practice.

When looking at flared joints the study actually confirmed the belief that flared joints are a large contributor to refrigerant losses: 21.6% of all leaks where in flares; 50% of the total amount was lost through these leaks. All in all it seemed that field assembled joints is the area to be looked at. 96% of all leaks where through field assembled joints – which should not come as a surprise. Looking at brazed joints only 0.16% of these joints had leaks. It was confirmed that systems with high leak rates mostly had leaks in inaccessible parts of the pipe-work – underlining the importance of above mentioned accessibility policies.

Figure 3 depicts the final results of this study and it indicates that median leak rates in Germany are probably lower than wide spread belief might suggest (It is common to hear of leak rates of 30% and more). What might come as a surprise is the fact that large systems have slightly lower leak rates than the total fleet of systems. One unit suffered a total refrigerant loss during the survey period. While this can never be avoided totally it appears doubtful that statistically one out of 62 units will loose its complete charge. In reality these accidents should be less frequent.

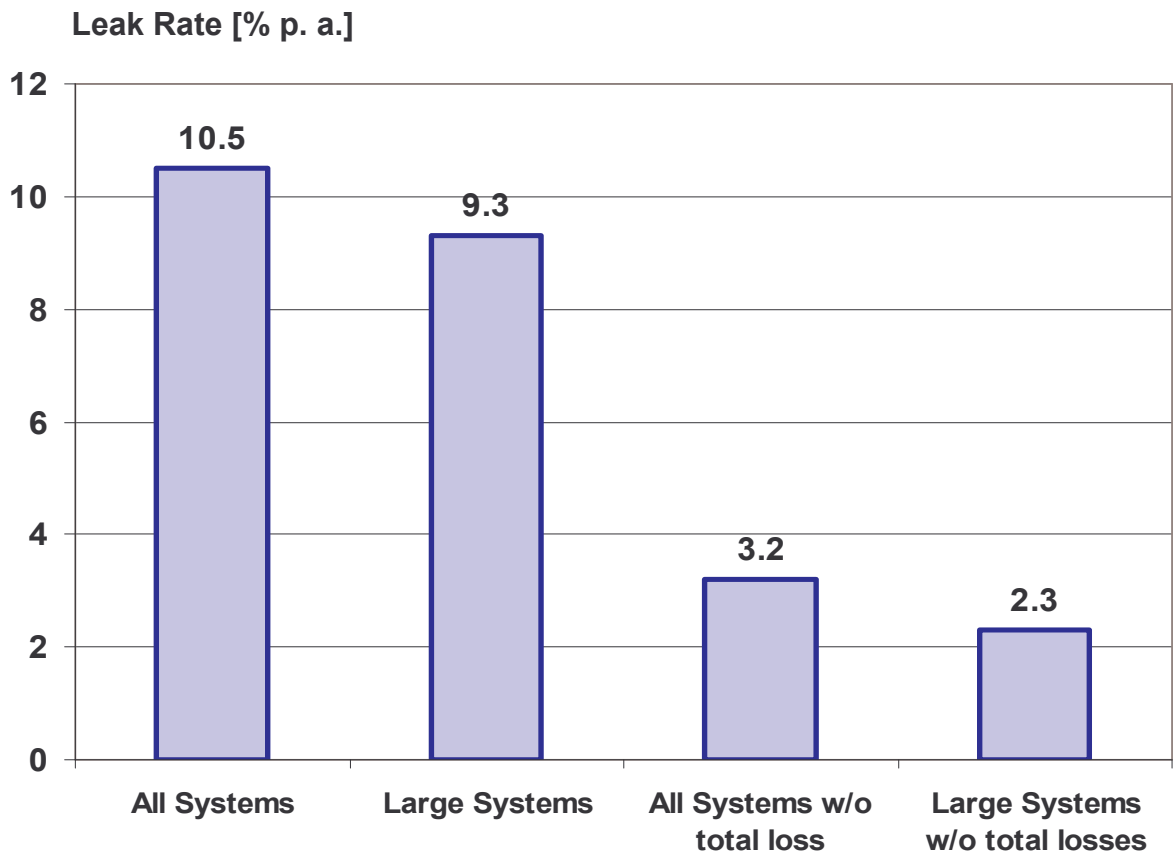


Figure 3: Statistical evaluation of leak rates in German supermarkets per [1]

As a follow up of this study and as a joint industry effort the FKT (Forschungsrat Kältetechnik – GER industry association) presented target leak rates for the industry. Figure 4 depicts these targets.

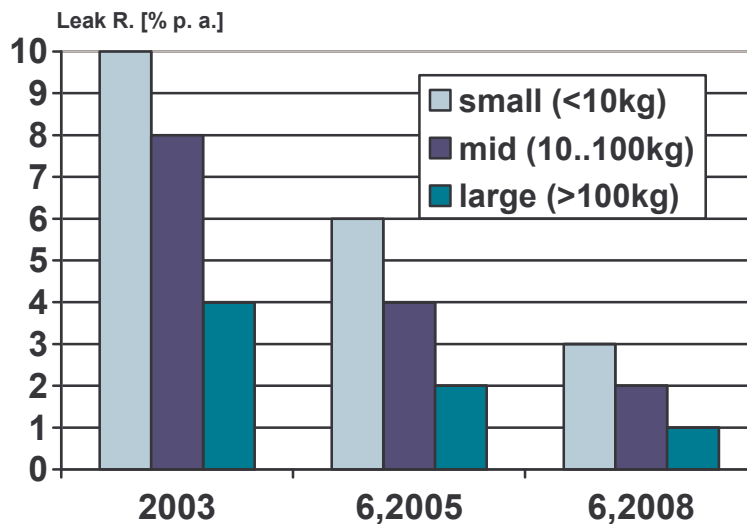


Figure 4: German industry targets for refrigerant leak rates in different system charge sizes.

The 2003 numbers represent the state of the art per [1] at the time of publishing these targets. In [4] more indication is provided that supports the order of magnitude of such leak rates. Here

leak rates of 5% p.a. in supermarket systems were presented as state of the art while 2% was quoted to be realistic target for optimized units.

In the Netherlands the success of the STEK regulation was overwhelming. In 2000 the annual leak rate of all monitored systems was 4,5%. Today's value (unavailable) is expected to be significantly lower. The regulation had many positive side effects. So called "odd jobbers" and "fly by nighters" were eliminated in the market as contractors have to be registered and certified in order to purchase refrigerant. Maybe even more important that the reduction in refrigerant leak rates is the fact that the overall energy efficiency of all systems monitored has also increased notably. Service -when carried out in a professional manner- can be very beneficial for energy efficiency. Cleaning of air-cooled condensers and permanent operation with optimum refrigerant charge sizes are some of the positive contributors in this respect.

Summary and Conclusion

The business structure for food retail and consequently for commercial refrigeration systems is different from country to country and cannot be generalized. France has the largest supermarkets in Europe, GER is a centre for hard discounters and the UK is a domain for freezer shops with very high installed refrigeration capacities per m² of retail space.

Legislators are addressing the issue of refrigerant leaks with a European approach to be expected in the near future. Already existing regulations (i.e. NL STEK) have proven to be successful with respect to reducing refrigerant emission while bearing additional positive side effects (improved energy efficiency).

The means to reduce refrigerant leaks are often simple. Some areas have demonstrated that leak rates of 2% p.a. in supermarkets are realistic and achievable - sometimes these values are reality today.

Bibliography

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