PRACTICAL IMPLEMENTATION OF LOW GWP A2L HFO BLENDS IN COMMERCIAL REFRIGERATION

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Introduction

Environmental legislation such as European F-Gas directive (EC 517/2014) and the need to move to lower global warming potential (GWP) refrigerants has encouraged many retailers to re-assess their future plans for refrigeration systems. The HFC phasedown effect on limiting the availability of high GWP refrigerants and the end use restrictions such as requiring <150GWP refrigerants for new systems >40kW capacity after 2022 requires a radical rethink of the refrigerants, and the technology required, to achieve these milestones.

Many retailers are investing in carbon dioxide or hydrocarbon based systems as a low GWP refrigerant options however some are not convinced that the overall benefits of these choices offer the optimum solution.

Asda in the UK is one such retailer and a crucial factor was to choose a solution that not only had a lower GWP but also that at least maintained the performance of the products it replaced with the energy efficiency being especially important as increased indirect emissions from increased power consumption will greatly reduce any net gain of lowering the refrigerant GWP. As already mentioned a popular solution being implemented by many retailers is the use of transcritical CO_2 systems and ASDA did look closely at this for its estate but concluded it did not meet the performance (including risk to trade) and safety criteria it had established for new technologies. In addition, ASDA was looking, if possible, for similar operating characteristics to the common HFCs such as R-404A and R-407F as well as the A1 HFO blends such as R-448A and R-449A being used to retrofit existing systems.

Using these selection criteria, ASDA recognised that there were 2 potential products that could fulfil their requirements, R454A and R454C, however both of these products are classified by ISO 817 as A2L i.e Mildly Flammable.

Refrigerant Choice Considerations

R-454C with a GWP of 148 was developed for applications where a GWP below 150 is required under the upcoming F-Gas equipment restrictions. This product performs well and can be used where the lowest GWP is desired in new equipment to replace a number of existing higher GWP A1 refrigerants including R-404A. In the case of the ASDA project, with packs operating below 40Kw capacity, it was not necessary to choose a refrigerant with a GWP below 150 and thus R-454A was considered. This has a higher GWP of 238

but was developed to be a close match for R-404A and its A1 replacements in new equipment. The GWP of 238 is low enough to ensure a sustainable future in new equipment while meeting ASDA stringent performance criteria. Theoretical performance vs. R-404A is shown below (Figure 1).

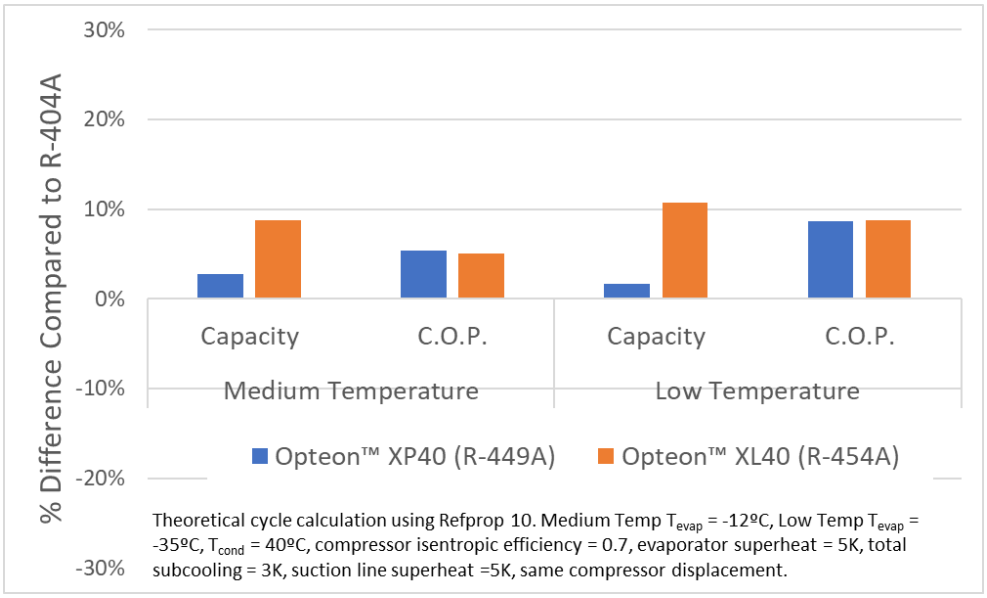

Figure 1 - Theoretical Performance Comparison of R-449A and R-454A vs R-404A

ASDA took the decision to trial the refrigerant in an existing system in an authorized access only zone; the ASDA Merchandising Center of Excellence (MCE) in Leeds over a six-week duration in early 2018. The results from this initial trial were excellent. No system commissioning settings were changed from the systems former refrigerant (R-448A) and very quickly it was established that it would be possible to raise the target suction setpoint to improve efficiency without having a detrimental impact on system performance. Based on these results ASDA and stakeholders moved onto the next stage; a trial in the new MCE at Pentair in Leeds. For this trial a new plant system was designed and developed by Hubbard Products to ensure compliance to ATEX and DSEAR regulations. Two independent plant systems were incorporated onto a single packaged plant frame – featuring technology designed to minimize charge size. The rationale was to ensure that the single plant frame matched the current size and 80kW medium temperature plant capacity – whilst meeting the guidance provided by BS EN-378.

Annex C of EN378-1:2016 sets out the criteria for determining the maximum allowable refrigerant charge. Within Annex C, Table C.2 specifically addresses the use of A2L classified refrigerants. The charge calculations are determined by assigning specific Access categories, Location classifications and Application. “Other applications” covers the use of A2L refrigerants for a commercial refrigeration pack. There are provisions set out in EN 378-1:2016 Annex C.3 that will allow larger charge sizes to be used with A2L refrigerants in other applications, provided additional safety measures are put in place.

Additional protective measures such as additional ventilation (natural or mechanical), safety shut-off valves, or safety alarms in conjunction with leak detection devices, must be employed. As can be seen in Figure 2, applying the required additional protective measures results in maximum charges above 50kg.

Risk Assessment — Flammability Considerations

Compliance with EN-378:2016 does not remove the requirement for a risk assessment. Although often overlooked, it has always been a requirement for risk assessments to be performed for any equipment utilising refrigerants, irrelevant of the flammability classification. The use of flammable refrigerants obviously poses potential additional risks and therefore any standard risk assessment processes used for A1 rated refrigerants must be reviewed to ensure that assessment of risks related to flammability are fully covered. For the ASDA project, individual risk assessments were performed at all stages of use, from design and manufacture, to installation/decommissioning, maintenance and normal usage stages. The risk assessment methodology was applied, including ATEX, with help and guidance from Business Edge consultant expertise. The knowledge gained from this process is providing a standard within ASDA and its refrigeration collaborators, as well as for commercial refrigeration users more generally interested in applying A2L technology. Within the European Union, the ATEX 137 Workplace Directive (1999/92/EC) is the primary guidance for consideration during the final installation.

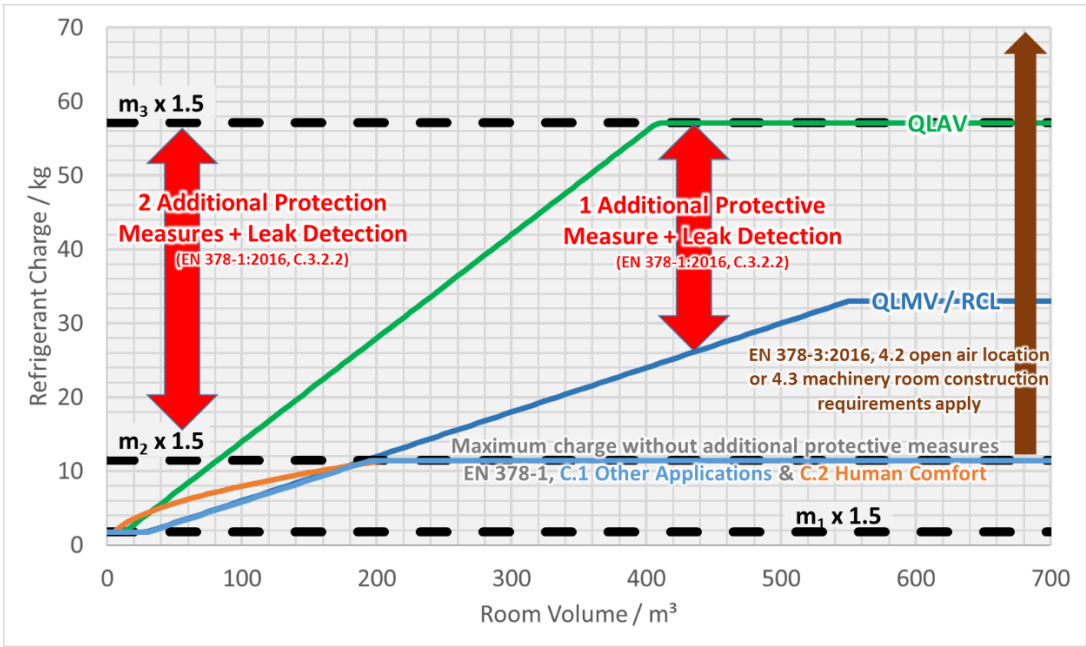

Figure 2 - Charge Size Calculations for R-454C within EN 378

This directive will be implemented at a national level in each country and may have a different name e.g. in the UK, the ATEX 137 Directive exists as the “Dangerous Substances and Explosive Atmosphere Regulations (DSEAR)”.

Interestingly, the UK DSEAR Regulation requires a DSEAR (ATEX) risk assessment for any pressurised gas, whether it is flammable or not, which means the risk assessment process when using a mildly flammable refrigerant, is fundamentally no different than using a non-flammable refrigerant, although using a mildly flammable refrigerant is likely to add some complexity to the process. It should be noted that in some countries additional national requirements may exist and users should ensure these are also considered.

The fundamental principles of the risk assessment, with regards to the formation of possible flammable atmospheres, are outlined in standard EN 60079-10-1:2015, which requires identification of:

- possible sources of release;
- rate, frequency and duration of any release;
- effectiveness of any ventilation;
- zone type (flammable atmosphere is present continuously, occasionally or not during normal operation);
- extent (size) of the zone.

The primary forms of ignition sources to be considered for refrigeration applications are those that produce energy in the form of heat, electricity, mechanical and chemical, although a full list and description of potential ignition sources can be found in EN 1127-1:2012.

Once the zones had been defined, any ignition sources within the zone were identified and removed, or controls put in place, to prevent an ignition event occurring should a flammable atmosphere occur. The flammability properties of A2L refrigerants are significantly different to those of A3 refrigerants such as propane and many potential ignition sources that would cause an ignition with propane are not ignition sources for many of the A2L refrigerants. The results from testing performed by the Airconditioning, Heating & Refrigeration Institute (AHRI Report no 8017) clearly show that many domestic electrical appliances and even friction sparks and smouldering cigarettes may not be considered as ignition sources when using A2L refrigerants. In fact, the cigarette was extinguished by the refrigerant within two minutes of being placed within the flammable refrigerant mixture.

Initial Performance Data from the Trial

The trial in the new MCE facility commenced in February 2019 and consisted of two purpose built packs by Hubbard using compressors supplied by Emerson and approved for use with HFO A2L blend refrigerants. The packs delivered <40kW and contained approx. 40kg of refrigerant. One pack was run on R-448A, an A1 HFO blend, and the other on the A2L low GWP R-454A. As well as a test of the performance of the A2L refrigerant, the set up was used as a test bed for the risk assessments, including DSEAR, and specifically of the measures to mitigate risk in such a system. These included ventilation, leak detection and developing a shutdown protocol should a leak be detected. This also gave an opportunity to optimise display cabinet design to accommodate A2L refrigerants, including the installation of leak detection equipment.

Energy monitoring data was collected by consultant engineers, Wave, from the two medium temperature packs following optimization of set points and running with comparative loads to ensure a valid comparison over a stable operation period. Analysis of the data by Wave showed an energy saving of 3.65% on the Opteon™ XL40 R-454A pack compared to the R-448A pack. It has already been reported that the A1 HFO blends R-448A and R-449A show a significantly improved energy performance when compared to R-404A in medium temperature operation and the implementation of the A2L refrigerant R-454A has given a further small improvement.

When taking into account the measured Energy benefits, increased charge (and therefore larger capacity system) sizes and the minimal design changes required a very recent study commissioned by Chemours has shown that compared to other low GWP technologies, using A2L very low GWP HFO blends give the lowest total emissions and lowest Lifecycle cost per kW of cooling (figure 3 &4) over a 10 year period.

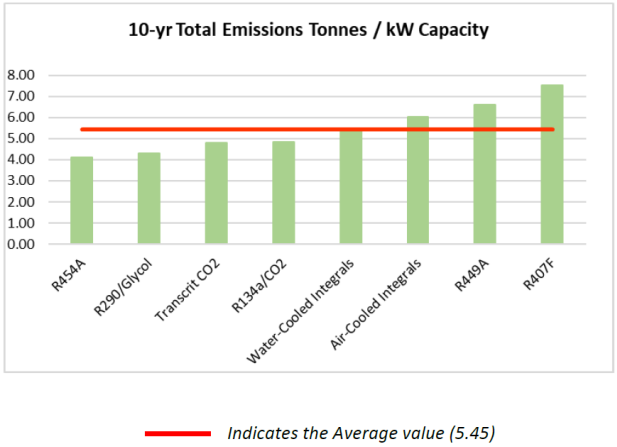

Figure 3 - Total Emissions vs Technology comparison

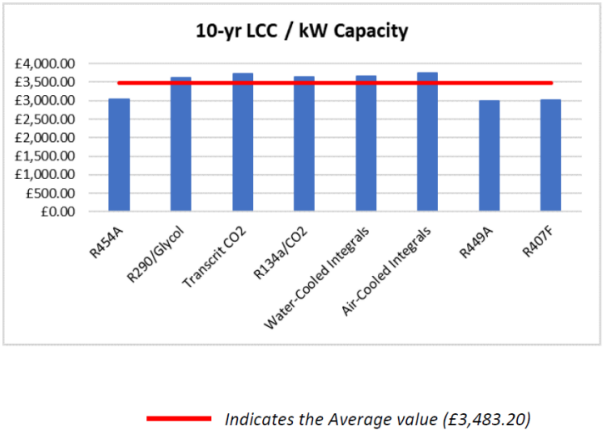

Figure 4 – Life Cycle Cost vs Technology comparison

Conclusions

This project has shown that utilising very low GWP A2L blends in distributed commercial refrigeration systems is a viable safe option to replace the traditional High GWP refrigerants (e.g. R-404A) with minimal design changes.

Compliance with environmental regulations such as the F-gas in Europe and the Kigali amendment of the Montreal Protocol and safety standards and regulations such as EN378 and ATEX are not barriers to implementation and do not have to introduce excessive additional capital or running costs to achieve the madatory reduction in refrigerant GWP.

Analysis of a number of other technologies including carbon dioxide and hydrocarbons has shown that very low GWP A2L HFO blends may have the lowest total emissions and lowest life-cycle costs meaning that widespread use of this technlogy will not only have the biggest impact on lowering climate changing emissions from refrigeration systems, but will also have the lowest cost impact.