

Evaluation of the Environmentally Friendly Refrigerant Ammonia According to the TEWI Concept

“The combination of a unique level of temperature increase in the late 20th century and improved constraints on the role of natural variability provides further evidence that the greenhouse effect has already established itself above the level of natural variability in the climate system. A 21st-century global warming projection far exceeds the natural variability of the past 1000 years and is greater than the best estimate of global temperature change for the last interglacial period.”^[1]

There is strong evidence that human emissions of greenhouse gases are changing the world's climate, and that is why Climate Change is one of the most important issues facing mankind today. The largest contributor to the problem is carbon dioxide (CO₂), produced when we burn fossil fuels like coal, oil and gas for energy. Considering that developed countries use approximately 15% of their total electricity supply for refrigeration and air conditioning ^[2], there are a number of challenges presented to this industry:

- Increasing the energy efficiency of cooling systems to reduce the amount of greenhouse gases produced by energy generation.
- Reducing the direct emissions of high global warming potential (GWP) refrigerants through improved service practices and better system integrity by design and manufacture.
- Avoidance of further depletion of the stratospheric ozone layer by reducing and eliminating the use of refrigerants with ozone depleting potential (ODP).

The latter is addressed through the structured phase-out outlined in the Montreal Protocol, whereas the former are only beginning to be tackled through the Kyoto Protocol and supporting national legislation. It is widely accepted that, on average, 20% of the global warming impact of refrigeration technology can be attributed to direct emissions of gases, with the remaining 80% a result of power consumption and the associated indirect emissions.^[2] These are the two areas that are considered in the most popular approach to the assessment and comparison of cooling systems: the Total Equivalent Warming Index, or TEWI. Whilst there are additional amounts of energy used in the fabrication, installation and

decommissioning of cooling systems, and these may be taken into account through more complex Life Cycle Climate Performance (LCCP) analyses, their relative weighting in comparison to direct and indirect emissions is often negligible.

Although the TEWI calculation centres on one simple equation, the result is dependent on a number of assumptions about equipment performance and use patterns, leakage rates, refrigerant properties and electricity generation efficiencies. For this reason the calculation needs to be guided by supporting documentation.^[3] It must also be stressed that, whilst the outcome of the analysis is a numeric value, the result is far more meaningful when used to compare two or more systems of equal duty and function.

In broad terms, the outcome of the comparison will be affected to the greatest degree by the relative energy efficiencies of the systems. A refrigeration plant possessing inherently efficient design features such as:

- A refrigerant with good exergetic efficiency
- A compressor with good efficiency and
- Good part-load operation (through techniques such as the use of variable speed drives)
- Evaporator and condenser with low approach temperatures
- Floating head (condenser) pressure to minimise compressor work in winter months

will display a far higher coefficient of system performance than, for example, a system with artificially inflated head pressure due to liquid injection oil cooling, undersized evaporators and condensers that provide a first-cost saving but result in higher condensing temperatures and lower evaporating temperatures, and a circuit construction and control philosophy that results in compressors, particularly screw compressors, operating at part load for extended periods.

All other things equal, vapour-compression systems designed to operate with ammonia will excel in reducing indirect emissions (i.e. CO₂). Ammonia possesses a tremendously high latent heat and therefore a far lower system mass flow rate is required to service a given heat load when compared to the majority of HFC refrigerants. This means that the energy input to the compressor is much reduced. Whilst ammonia provides very good efficiency over its whole operating range (-40°C to +40°C), its performance can be equalled or bettered in high temperature (i.e. air conditioning) applications by R123 in centrifugal chillers, R22 or R410a. R123 and R22 are due to be phased out by 2015 in developed countries and, whilst

there is no replacement that can match the efficiency of R123 in centrifugal chillers, ammonia equals or better the performance of R22 in low temperature applications.

Although there are refrigerants that may equal or marginally better the efficiency of ammonia, none of them have a zero GWP. Ammonia does, and therefore has a distinct advantage that becomes apparent in the calculation of the TEWI. Whilst leakages of ammonia are not encouraged for safety reasons, any emissions that do occur will not contribute to global warming. In addition, leakages can be detected and eliminated quickly, thereby minimising the chance of a system running at less than peak efficiency due to low refrigerant charge.

In comparison, the TEWI figure for a system operating on an HFC will, in most cases, be significantly larger. Besides the fact that their indirect emissions are usually higher than those of an ammonia system due to lower energy efficiency, even moderate leakage rates contribute considerably to the direct emissions owing to the large specific GWP of synthetic refrigerants e.g. 1kg of R404a has the equivalent GWP of 3260kg of carbon dioxide. Another point to consider is that most (if not all) man-made refrigerants are odourless and colourless and therefore a large proportion of the system charge might be lost before the operator or maintenance company becomes aware of low levels or declining system performance. It is the aim of recent legislation such as the European F-Gas regulation to mandate regular leak tests of refrigeration plants and the installation of permanent leak detection systems in the case of large refrigerant charges.

Ammonia is an excellent choice of refrigerant for many applications and its sphere of use has broadened considerably thanks to its excellent energy efficiency and negligible environmental impact. In addition, it is not subject to the uncertainty facing HFC refrigerants of possible future legislation limiting or even banning its use, making it a future proof application. Key to its successful application has been improvements in component and system design and the appropriate application of safety measures, such as those outlined for ammonia in EN378. Such measures include design for minimum (critical) charge, contained primary circuit servicing a distributed secondary fluid system, site specific risk assessments and the provision of safety equipment and emergency procedures.

References

- [1] Crowley, Thomas J.; "Causes of Climate Change Over the Past 1000 Years" *Science* 14 July 2000: Vol. 289. no. 5477, pp. 270 – 277.
- [2] International Institute of Refrigeration (IIR) Statement: "Global warming: refrigeration-sector challenges", Eleventh session of the Conference of the Parties (COP11), First session of the meeting of the Parties to the Kyoto Protocol (COP/MOP1), Montreal, Canada, November 28 – December 9, 2005.
- [3] British Refrigeration Association (BRA): "Guideline Methods of Calculating TEWI, Issue 2 (2006)".

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