

Comparison

Ammonia / Secondary Refrigerant System against Direct Evaporation of HCFCs /HFCs

1 Introduction

In the following discussion, the attempt is made to emphasize the economic and ecological advantages of the refrigerant ammonia.

As in a comparison not solely technical aspects but moreover economic aspects play the important role, this comparison is not necessarily facilitated. By this, we do not mean that state-of-the-art systems are uneconomic. On the contrary. However, economic decisions often lead to designs which do not comply with the state of the art and, therefore, do not represent an optimal solution in economic effectiveness (energy costs, maintenance costs, equipment safety, product quality of frozen goods etc).

A further point to be mentioned is that a refrigeration system with direct evaporation very often does not run along the predicted and calculated parameters (components: evaporator and expansion valve). Therefore, a comparison of systems with theoretically determined data is extremely questionable.

Thus, a serious comparison would only be possible if two systems are installed side by side. In the case of refrigerated storage rooms, for example, these would have to be loaded with the same quantities of products etc.

We should not fail to mention that at present indirect systems are only an interesting solution from a certain size upward. The larger a system is and the longer the piping, the clearer become the advantages of indirect cooling. However, by the technological development smaller and smaller systems become economically advantageous.

The comparison relies on both theoretically determined data and experiences from two projects in the years 1996 and 1997, which were made with the systems (indirect/NH₃ and direct/HFC).

We exclude a comparison of secondary refrigerant systems with ammonia or HFCs as refrigerants from our discussion as ammonia in comparison to all commercially available HFCs has essential thermodynamic and thermokinetic advantages as a refrigerant.

(Note: The use of electronic injection valves can increase the economicalness of a direct system. As the conducted projects focussed on investment costs, this aspect is not discussed here.)

To summarize, it can be said that various parameters make a direct comparison extremely difficult, for example:

1. The different requirements on the refrigeration system.
2. A direct comparison of the system types is not possible.
3. There is a discrepancy between theoretically achievable values and the practical operation.
4. The arguments in an evaluation of refrigeration systems and refrigerants are not always rational.
5. In practise, strategic considerations often play an important role in determining the price for a product.
6. There are no standardized practical applications of NH₃ systems in commercial refrigeration yet.
7. There is a great number of refrigeration systems which have to be compared with each other.

Nevertheless, we would like to draw some comparisons below, which are intended to demonstrate the advantages of indirect NH₃ systems.

2 Production Costs

The general notion that the investment costs for a NH₃ refrigeration system are by 10% to 25% higher is not true any longer.

Practical experiences have proved that there is no disadvantage for indirect NH₃ systems of a certain size and upward as far as production costs are concerned. As mentioned above, it is not possible to make a general recommendation about the minimum size a secondary refrigerant should have. In order to come to a conclusion here, information about the refrigeration performance, number of refrigerated areas and the piping system is required.

The prices of goods and services offered on the free market should be used as a guideline for production costs. This offers more meaningful results than internal studies.

Saving Potentials:

As machine sets, standardized systems should be used as they have a cost reducing effect. Saving potentials exist in the fields of installation as well as in service and maintenance.

Liquid chillers with the following characteristics are already regarded as the standard:

- two separate refrigeration cycles (fail-safe operation)
- plate heat exchanger/evaporator with special liquid distribution
- dry expansion with electronic expansion valve
- plate heat exchanger/condenser
- frequency changers controlled secondary refrigerant pumps
- installed and completely wired power and control cabinets

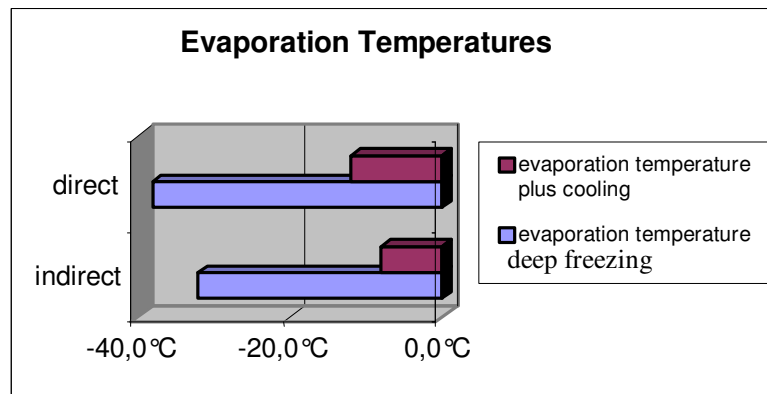
Clients as well as various manufacturers of refrigerated cabinets often think that conventional refrigerated cabinets are not suitable for direct evaporation, the operation with a secondary refrigerant. Experience has shown that apart from changes in the collecting of the piping no other modifications are required. Thus, a conversion of the refrigerated cabinet, regarded as very expensive, is not necessary.

If the piping system is made of plastic, this results in saving potentials with regard to assembly time and less expensive insulation as well as cost of purchase.

3 Running Costs—An Energetic Evaluation

The running costs of an indirect ammonia system approximately equal those of a direct evaporation with HCFC as the refrigerant. Here, we would like to point out that we mean the costs caused by full load operation and not those by part load which represent the

predominant number of operating hours. In the field of part load operation, indirect cooling is much more favourable.



The decisive criterion for the evaluation of refrigeration systems is the suction and condensation pressure measured at the compressor.

In the case of existing systems it could be determined that for example in supermarket refrigeration systems:

In indirect NH₃ systems
the suction gas temperature ranges

from -9°C to a maximum of -11°C for plus systems and
from -32°C to a maximum of -34°C for minus systems.

In direct systems of similar size
suction gas temperatures ranging

from -13°C to -17°C for plus systems and
from -37°C to -41°C for minus systems could be determined.

Each Kelvin lower evaporation temperature reduces the refrigeration performance of plus systems by ca. 4% and of minus systems by ca. 6%. This means that an ID system compensates for the additional pump energy required by considerably higher evaporation temperatures.

It needs to be mentioned, however, that the respective suction gas temperatures depend very much on the particular refrigeration cabinet models. The same applies, of course, to NH₃ indirect systems.

The decisive factor for an energetically optimal indirect NH₃ system is that an as high as possible evaporation temperature is achieved.

In optimally adjusted systems for some refrigeration cabinet models, a flow temperature of the secondary refrigerant of only -6°C during opening times and a secondary refrigerant temperature in closed refrigeration cabinets (glass lids, glass doors) and refrigerated rooms of only -4.5°C is necessary in order to achieve and ensure the required product temperature. For minus refrigeration cabinets a flow temperature of -29°C to -30°C of the secondary refrigerant is sufficient to ensure the appropriate product temperature (-18°C to -22°C).

3.1 Reduction of the Refrigerant Charge

Secondary refrigerant systems reduce the refrigerant charge to a fraction in comparison to direct HFC systems. Above all, due to the existing environmental situation this point becomes more and more important.

Indirect plants are divided into three systems. It is this division which enables the drastic reduction of the refrigerant charge to amounts from 0.01 kg/KW to 0.03 kg/KW.

First system: Refrigeration with the main components driving motor/
compressor/evaporator/expansion valve/separator/oil cooler/
condenser.

Second system: cold/refrigeration distribution system with piping/pump
groups/valve stations/air coolers in the refrigerated areas.

Third system: return cooling cycle with heat recovery/piping/pump groups/
heat exchanger with additional usage of evaporation heat.

Dividing the plant system into three guarantees minimal refrigerant charges in the refrigerant pipes of the compact system.

3.2 Leakages and Leakage Costs With an Example

Leakages in direct systems occur time and again. Despite repeated statements to the contrary, leakages can also occur in carefully and competently constructed systems and are extremely difficult to detect. Currently the average leakage loss of a direct system is about 10% to 20% annually.

It is a fact that leakages can often only be repaired after several inspections of the entire system (which means several employments of the service contractor and several rechargings of the system). The arising costs have to be born by the user of the system. These costs can be minimized considerably by the use of the indirect system.

The following example is given (prices on the basis of 1996):

Purchase prices of refrigerants and secondary refrigerants in DM including possible losses.

	Charge	purchase costs	Possible losses
direct/R404a	1,300 kg	<u>ca. 90,000.00</u>	10%-20%
indirect/NH ₃			
NH ₃	45 kg	ca. 900.00	< 1%
secondary refrigerant minus cooling thermogen VP 1869	3,000 l	ca. 25,000.00	3% - 5%
secondary refrigerant plus cooling propylene glycole (30%)	3,000 l	ca. 13,000.00	3% - 5%
total indirect/NH ₃		<u>ca. 38,900.00</u>	

It turned out that leakage rates of 10% to 20% are quite usual in systems with fluorinated refrigerants. With < 1% the leakage rates of NH₃ systems are negligible.

In the case of indirect NH₃ systems, costs for leakages on the secondary refrigerant side of about 5% may have to be added.

Additionally, these leakages do not only cause costs for recharging but also costs due to damages to the stored products, interruptions etc.

The losses do mainly occur when maintenance and repair work is done. Also, the secondary refrigerant pipes are very tight. Another advantage of a secondary refrigerant system is that a leakage can be detected very easily.

3.3 Defrosting Systems—Costs for Defrosting

Indirect NH₃ refrigeration systems offer excellent opportunities for energetically highly efficient defrosting systems at refrigerated plus as well as minus areas. The defrosting systems of an indirect plant offer further essential advantages.

1. Defrosting Methods Plus Cooling:

- ◆ secondary refrigerant circulating system: medium temperature of a maximum of +8°C

How can the heat required for defrosting be “generated“ now?

- Centralized
 - by the waste heat of the circulation pumps
 - by refrigerated areas with higher ambient temperatures
 - in combined systems (indirect/direct) by the condensation heat of the refrigerated minus areas
- Decentralized
 - by new defrosting systems which are self-sufficiently installed in the cooler

Piping system: Only one piping system is required. The secondary refrigerant pipe is used for
defrosting.

2. Defrosting Methods Minus Cooling:

- ◆ separate flow and return pipes. Medium temperature from +10°C to +20°C.
- Centralized
 - by using the waste heat of superheating
 - by using the waste heat of condensation

- Decentralized
 - by new defrosting systems which are self-sufficiently installed in the cooler. No separate piping system is required.

ADVANTAGES and DISADVANTAGES of These Defrosting Systems

- Fast and efficient defrosting
- Modest temperature rise in the product area
- Energetically favourable by the use of waste heat
- Modest mechanical stress of the refrigeration components during the defrosting process in comparison to electric defrosting and hot-gas defrosting
- In the case of decentralized brine defrosting in the cooler, the individual coolers can be defrosted as required.
- Decentralized defrosting in minus cooling systems causes additional costs for a separate piping system.

4 Servicing and Maintenance Costs

The costs for routine servicing are almost identical for the two systems. However, the maintenance costs (leakages, leak detection, etc.) except for routine inspections are not as high as for a direct system. Additionally, it may be mentioned here that it is far easier and financially more favourable to extend a plant with an indirect system. This applies on the condition that these required additional capacities had been taken into account in the planning stage for the piping and the pump capacity.



Engine room of an indirect NH₃ system in a hypermarket

5 Comparison Indirect / NH₃ against Direct / HFC¹

System characteristics	Indirect/NH ₃	Direct/R404a
Plus cooling	2 screw compressors 1 plate heat exchanger/evaporator dry expansion 1 electronic expansion valve	2 compound compressor systems = 8 reciprocating compressors 53 evaporators 53 therm. Expansion valves
Refrigeration capacity	380 kW	326 kW
Evaporation temperature	-10°C	-12°C/-17°C
Temperature of secondary refrigerant	-7°C/-3°C	---
Condensation temperature	max. 35°C Average annual Temperature +25°C	max. 43°C average annual temperature +32°C
Defrosting system	Secondary refrigerant +7°C	circulating air / electric defrosting
Condensation	Plate heat exchanger/compressor open heat exchanger	evaporation condenser
Secondary refrigerant pumps	heat entry in the secondary refrigerant system ca. 2% of the refrigeration performance	---
Minus cooling	2 screw compressors 1 plate heat exchanger 1 electronic expansion valve	2 compound compressor systems = 7 reciprocating compressors 27 evaporators 27 therm. expansion valves
Refrigeration capacity	110 kW	97 kW (31 kW + 66 kW)
Evaporation temperature	-33°C	-36°C - -41°C
Secondary refrigerant temperature	-29°C / -26°C	---
Condensation temperature	max. 35°C	max. 43°C
Defrosting system	Heat carrier	hot gas/electric defrosting

Secondary refrigerant pumps	Heat entry in the secondary refrigerant System Ca. 3.5% of the refrigeration performance	---
Refrigerant charge	65 kg	1,200 kg
Refrigerant loss	ca. 10% - 20% due to servicing	ca. 10% - 20% due to leakages
Fans Open heat exchangers Evaporation condenser	ca. 7% of the electric energy	ca. 8% of the electric energy
Total P_e	240 kW	202 kW
Σ_{KA} plus/minus	2.067	2.09
Investment costs %/kW refrigeration capacity	100%/kW	112.54%/kW

¹ This comparison was made on the basis of two actual offers. The different refrigeration capacities are due to the fact that in the case of the indirect/NH₃ system a reserve for refrigerated cabinets and rooms was taken into consideration. The indirect/NH₃ system was realized because of the lower investment costs.

6 Product Quality

Due to the higher evaporation temperature and the relatively high secondary refrigerant temperature in the refrigerated areas, less frost forms at the air coolers and the product. It is a positive side effect that here fewer defrosting phases are necessary. This saves additional energy.

As the temperature in the refrigerating cabinet is more steady, the product quality is much better than at a very low evaporation temperature and several defrosting processes during one day.

4 crucial points ensure the product quality and thus the competitiveness of the plant owner:

1. the right temperature
2. the steady temperature
3. the right humidity
4. the right air velocity

The first three points can be achieved better with an indirect refrigeration system. Point 4. is independent of the system employed.

7 Future Prospects

In conclusion, it can be stated that indirect NH₃ systems can definitely be seen as an alternative to the present “classic” direct systems. Neither with respect to the manufacturing costs nor to the running costs does the projecting according to the state of the art result in any disadvantages for an indirect NH₃ system.

The ID system results in essential advantages, such as product quality and environmental protection as well as cost reductions in maintenance and routine servicing costs.

The essential thing is that an indirect NH₃ system shows great differences to a direct system. These have to be taken into consideration when projecting the system.

The design of an indirect system supports the trend towards compact refrigerating units and uncomplicated “plug-in” solutions.

For the short or medium term this trend will become effective and will determine the competition in refrigeration engineering. The less complicated a plant system is, the better and easier the required temperatures can be ensured, the more fail-safe plants have to be constructed, the better are the chances for indirect NH₃ systems.

Because of the considerably higher charges of HFCs and the associated losses due to maintenance and leakages, the TEWI value is less favourable. Due to the use of indirect systems, the focus in the evaluation of environmentally relevant features shifts from the global warming impact resulting from leakage losses to the energy consumption of a refrigeration plant.

If an overall evaluation of the environmentally relevant data of refrigeration plant systems is required by law as a prerequisite for a certification of this plant, it is not possible to avoid an indirect NH₃ system.

The combination of an indirect NH₃ system with a direct system (plus cooling indirect/NH₃, minus cooling indirect/decentralized HFC cascade) also can be regarded as forward-looking. Here, the advantages of both systems are combined and joined together to a new refrigeration system. These systems can unite the advantages of the different systems.

In summary, it can be said that for various reasons (environmental protection, technological innovation, legislation, etc.) a multitude of system types is again possible.



Sales room of a hypermarket—glass doors for the deep-freeze cabinets with combined storage facilities and loading of the shelves from the back.

However, it should always be the main objective to reduce the consumption of primary energy in refrigeration directly where the "generation of cold" occurs.

Conclusion:

An indirect ammonia plant should always be projected and operated as an indirect plant. In indirect systems, too, ammonia shows its advantages as an environmentally friendly and cost-saving refrigerant. To regard and project an indirect system only as a variant of a direct system, does not make use of the advantages of the plant system.

In case of doubt, the German-language original should be consulted as the authoritative text.

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