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APPLICATIONS BULLETIN

PRACTICAL APPLICATION INFORMATION FOR THE MCQUAY SALES FORCE

This Application Bulletin is part of a Refrigerant Toolkit McQuay International has produced for you. The bulletin itself deals with common misconceptions in the market place that you have to deal with daily. The support Application Guide, Refrigerants, AG 31-007, is a comprehensive document with background information on all aspects of refrigerants. You should make yourself familiar with this material. There is also a PowerPoint presentation available from McQuayBiz that follows the Application Guide. It includes speaker's notes and can be edited to meet your specific needs. This toolkit can be used to train your staff, do lunch and learns or even ASHRAE technical sessions. Note that the Applications Bulletin is a commercial document and therefore not appropriate at an ASHRAE meeting.

Refrigerants

In the mid-1990s CFCs were phased out by the Montreal Protocol. Prior to that, few people would have discussed refrigerants as a reason to buy one machine over another. Once the transition away from CFCs was required, refrigerants moved to the forefront and became a driving factor in equipment selection. Since then, the Refrigerant wars have died down, but with the current cap and upcoming phaseout of HCFCs, they again are becoming the topic of discussion. This Application Bulletin is about what other equipment manufacturers are saying about refrigerants. It will help dispel the "marketing" that is taking place and provide solutions that can be used to assist our customers.

R-22

R-22 is the most popular refrigerant in the world. It is classified as an A1 (lower toxicity – no flame propagation) HCFC. In the United States, the EPA is phasing out R-22 in 2010. No single refrigerant will replace R-22. Different refrigerants will each take a piece of the broad market that R-22 was used in. For air conditioning applications, R-134a, R-407C and R-410A will replace the bulk of applications R-22 is currently used in. It has the largest installed inventory available for reclamation. As new technologies are developed and tested, the owner can move away from R-22.

R-407C and R-410A

These two refrigerants are HFCs and classified as A1 (lower toxicity – no flame propagation) by ASHRAE Standard 34, Designation and Safety Classification of Refrigerants. R-407C is a close "drop in" refrigerant to R-22. It can be used in a R-22 system without major modifications. It does have an 8°F glide, which effectively rules out flooded evaporator applications such as York's large tonnage R-22 centrifugal chillers. Efficiency tends to drop from an R-22 design. R-407C allows field retrofits and current product offerings to be converted to an HFC refrigerant. The equipment manufacturer should be consulted for their advice and concerns regarding a retrofit. Performance in product lines that have been converted should be monitored but if the EERs or kW/ton are acceptable, then R-407C is possible solution to avoiding HCFCs.

R-410A operates at higher pressures than R-22. Its volumetric capacity is 1.5 cfm/ton as opposed to 2 cfm/ton for R-22. R-410A requires completely redesigned refrigeration systems. It is entering the market through the residential and small component commercial sectors first. This is where compressor and other technologies required to build a R-410A system are initially being developed. McQuay has already built screw chillers using R-410A and has the most experience at using it in large systems.

Concerns about R-410A's higher operating pressure are unwarranted. The higher pressures have to be accounted for in the design, but it is straightforward engineering along with proper system design and installation (we would say this about any refrigerant), R-410A can be used appropriately within the catalog ratings of the manufacturer. If the performance is satisfactory, then using R-410A is an excellent solution.

McQuay® Air Conditioning

R-134a

Simply put, R-134a is the work horse refrigerant of the foreseeable future. In large tonnage systems (over 100 tons) it will shortly replace R-22 as the most popular refrigerant in the world. R-134a is classified as an A1 (lower toxicity – no flame propagation) HFC. It is the refrigerant of choice for the automotive and appliance industries. All second generation screw and centrifugal chillers have been based on R-134a. The big four air conditioning manufacturers have followed McQuay's lead and now offer a R-134a centrifugal chiller and are now converting their screw chiller products over to it as well. There is no phaseout date for R-134a by either the Montreal Protocol or the Kyoto Protocol.

R-123

R-123 is classified as a B1 (higher toxicity – no flame propagation) refrigerant. It is an HCFC and as such will be phased out by the Montreal Protocol. Both its production and consumption levels have been capped in the United States by the EPA. If the EPA introduces an allocation procedure (they will do this if the United States approaches the Montreal Protocol cap), HCFC production and consumption will be lowered to meet the cap. These levels would be reviewed on a year by year basis and the EPA would adjust the levels as required to meet the phaseout schedule of the Montreal Protocol. R-123 cannot be used in new equipment beyond 2020. A small amount is available for service purposes until 2030.

R-123 is only used in negative pressure centrifugal chillers. Unlike the CFCs in the past or R-22 now, which have huge installed inventories, there is relatively little R-123 being produced or installed in the field. R-123 consumption is only a few percent of the 15,240 metric ton HCFC consumption cap in place for the United States by the Montreal Protocol. Once the phaseout occurs, customers will not enjoy the availability of R-123 in the same manner as R-11 or R-12.

Most of the mis-information evolves around R-123. Each of the common misconceptions is dealt with below.

R-123 is the most efficient refrigerant (table 1)

Efficiency is a refrigeration system property, not a refrigerant property. McQuay's Application Guide on Refrigerants (AG 31-007) goes into great detail on refrigerant properties and system efficiency, and the reader should review the material. Here is the short version:

The best efficiency possible is based on the Carnot cycle, which does not even take into account the fluids being used.

The next model is an Ideal Cycle. This model assumes an isentropic (100% efficient) compressor, perfect heat transfer (zero approaches in the evaporator and condenser) and no transport losses (no pressure/temperature changes in the piping or components). In this model, R-123 is slightly (3%) more efficient than R-134a. So, the phrase "123 is the most efficient refrigerant" is accurate under these conditions.

However, no one can build a refrigeration system based on an ideal cycle. In the real world, heat transfer and transport properties must be accounted for which directly affect suction and discharge pressures. Actually, R-134a has better heat transfer and transport properties than R-123. Once these two additional refrigerant properties are included in the model, the tables can be turned and R-134a becomes the most efficient. All of this should be taken with a grain of salt because to truly optimize each refrigerant, different refrigerant cycles would be used (subcooling for R-134a – such as in McQuay Distinction™ chillers or multistage compressors for R-123)

In the end what is important is kW/ton and in particular IPLV. The most efficient chiller available is a McQuay dual compressor chiller with VFDs.

R-123 is the most environmentally balanced refrigerant (table 2)

The two main parameters for measuring the environmental impact of a refrigerant are Ozone Depletion Potential (ODP) and Global Warming Potential (GWP). Any refrigerant that has an ODP greater than zero has been or is being phased out by the Montreal Protocol. The reason CFC and HCFCs are being phased out is that refrigerants are a major contributor to the anthropogenic (manmade) damage caused to the ozone layer. Refrigerants currently account for 28% of anthropogenic ozone depletion. Over the next century, they will account for 24%.

Figure 1 shows a table often used to suggest that "the average of GWP and ODP" is the best indicator of a refrigerant's environmental impact. The figure is technically accurate. It has ODP on one side and GWP on the other side. However, it is extremely misleading. Whereas refrigerants play a key role in ozone depletion, they play a minor role in direct effect global warming. Refrigerants will only account for 3% of the long-lived anthropogenic greenhouse gases. The problem with Figure 1 is the scale of the two factors. A bar on the GWP side is not nearly as important as a bar on the ODP side, yet they are scaled the same. This is the reason that all the countries in the world decided to eliminate CFCs and HCFCs while only controlling emissions for HFCs.

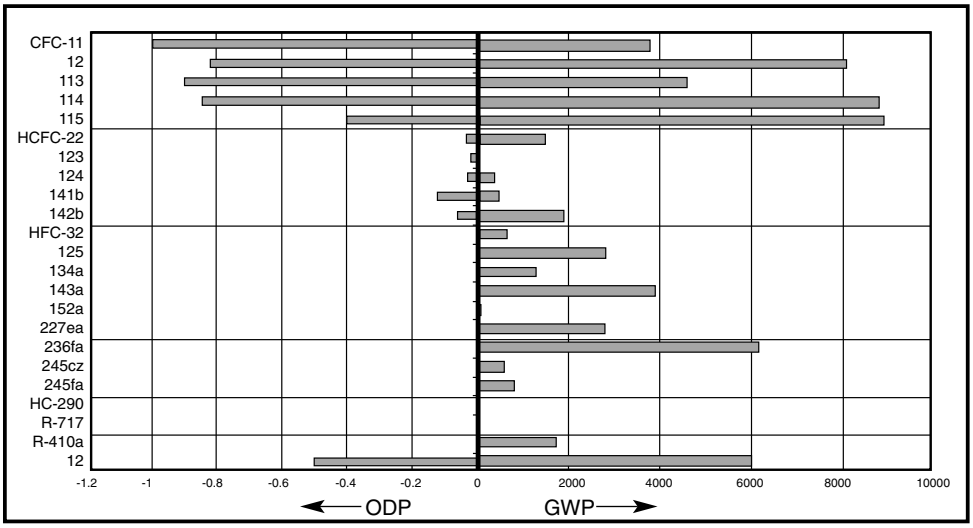
Table 1

Model	Carnot	Ideal Cycle		Base Model		Base Model w/ Non condensables	
Property		**R-123**	**R-134a**	**R-123**	**R-134a**	**R-123**	**R-134a**
Chilled water Supply Temp (°F)	44	44	44	44	44	44	44
Cond. Water Supply Temp (°F)	85	85	85	85	85	85	85
Compressor Inlet Temp (°F)	44	44	44	41	42	41	42
Compressor Outlet Temp (°F)	95	95	95	97	96	99	96
Suction Line Press. Drop (°F)	N/a	0	0	1	1	1	1
Liq. Line Press. Drop (°F)	N/a	0	0	1	1	1	1
Evaporator Superheat (°F)	N/a	0	0	0	0	0	0
Condenser Subcooling (°F)	N/a	0	0	9.5	9.5	9.5	9.5
Isentropic Compressor Eff.	N/a	100%	100%	84%	85%	84%	85%
Compressor Motor Eff.	N/a	100%	100%	100%	100%	100%	100%
COP	10.88	8.949	8.472	6.444	6.506	6.201	6.506
KW/ton	0.323	0.393	0.415	0.546	0.541	0.567	0.541

Table 2

Refrigerant Number	Chemical Name	Chemical Formula	Molecular Mass	Safety Group	Atmospheric Lifetime (Yrs)	ODP	GWP
11	trichlorofluoromethane	CCl_3F	137.4	A1	50	1	3800
12	dichlorodifluoromethane	CCl_2F_2	120.9	A1	102	1	8100
22	chlorodifuoromethane	$CHClF_2$	86.5	A1	12.1	.055	1500
32	difluoromethane	CH_2F_2	52	A2	5.6	0	650
123	2,2-dichloro-1,1,1-trifluoroethane	$CHCl_2CF_3$	153	B1	1.4	.02	90
125	Pentafluoroethane	CHF_2CF_3	120	A1	32.6	0	2800
134a	1,1,1,2-tetrafluoroethane	CF_3CH_2F	102	A1	14.6	0	1300
245fa	1,1,2,2,3-Pentafluoropropane	$CHF_2\ CH_2\ CF_3$	134.05	B1	8.8	0	820
290	Propane	$CH_3CH_2CH_3$	44	A3	<1	0	~0
404a	R-125/143a/134a (44/52/4)			A1			3260
407C	R-32/125/134a (23/25/52)			A1		0	1530
410A	R-32/125 (50/50)			A1		0	1730
500	R-12/152a (73.8/26.2)			A1		.74	6010
507a	R-125/143a (50/50)			A1			
600	Butane	$CH_3CH_2CH_2CH_3$	58.1	A3	<1	0	~0
717	Ammonia	NH_3	17	B2	N/A	0	0
718	Water	H_2O	18	A1	N/A	0	<1
744	Carbon dioxide	CO_2	44	A1	N/A	0	1

Figure 1



R-123 will get an exemption to the Montreal Protocol for Refrigeration Applications

Accepting the argument that R-123 is the most "environmentally balanced" refrigerant it becomes easy to extend the suggestion that there will be an exemption from the Montreal Protocol for its use as a refrigerant. This is just a supposition. There is no item on the agenda for UNEP to even consider extending the phaseout. Phrases like " while the scientific justification for a reprieve for R-123 are strong…" are based on a couple of papers written by very respected people. These people are in the minority. The overwhelming majority is for eliminating ozone depleting substances.

Implying refrigerant applications are unique is also a concern. While only 27% of CFC in the atmosphere came from refrigeration, 83% of HCFCs in the atmosphere are due to refrigeration. Exempting refrigeration is exempting the largest source.

To get an exemption for R-123, the Montreal Protocol would need to be changed. That would require a majority vote of all Montreal Protocol parties. Europe doesn't use chillers with R-123 right now. The European community has agreed to phase out HCFCs in advance of the Montreal Protocol (2015) and several countries such as Germany, Sweden, Norway, and Austria have already completely phased out HCFCs. Almost all R-123 production is consumed in the United States in equipment manufactured by two companies, both of which have alternative technology (R-134a chillers) in their product lines right now. No one can guarantee what will happen by 2030 but an exemption seems nearly impossible.

R-134a will be phased out too so it doesn't matter which one you pick

Innuendo about a phaseout for R-134a stems from HFCs being one of the 6 greenhouse gases included in the "basket" by the Kyoto Protocol. The Kyoto Protocol does not restrict usage of the six substances (including HFCs), just emissions. That is quite a bit different from the Montreal Protocol, which is substance specific and does restrict usage. There is no phaseout for HFCs by either the Montreal or the Kyoto Protocols.

Some countries in Northern Europe have proposed legislation to phase out HFCs. Their climates allow them to be less dependent on air conditioning and hence HFCs but these countries are the exception.

R-123 is safer than R-134a (figure 2)

The fact is R-123 is classified by ASHRAE Standard 34 as a B1 (higher toxicity – no flame propagation) refrigerant. R-134a is an A1 (Lower toxicity – no flame propagation) refrigerant. To deflect attention away from toxicity issues, the game that gets played is over pressure. Proponents of R-123 will point out that R-123 is a liquid at mechanical room conditions (it boils at 82°F) while R-134a is a gas. They will say if there is a major leak,

Figure 2

	Lower Toxicity	Higher Toxicity
Higher Flammability	A3	B3
Lower Flammability	A2	B2
No Flame Propagation	A1	B1

R-123 will lie on the floor in a puddle and allow occupants a chance to evacuate. A very powerful but foolhardy demonstration is sometimes done by opening jars of the two refrigerants in front of customers. Then they connect this demonstration to an event where someone was asphyxiated in a room full of R-22. They make it sound like positive pressure refrigerants present a very real and dangerous situation.

The reality is that catastrophic leaks are extremely rare. As well, a positive pressure refrigerant such as R-134a is not guaranteed to flash to gas. If a large amount of liquid R-134a spills, some would evaporate and sub-cool the remaining refrigerant, keeping it in liquid form and provide time for people to leave the area.

Accidentally entering a room where a major leak had occurred is a possibility for either R-123 or R-134a. Both could displace enough air to create a threat. That is why almost all mechanical rooms are equipped with refrigerant monitors to warn personnel of refrigerant leaks. If a mechanical room is built to the specifications outlined in ASHRAE Standard 15, Safety Code For Mechanical Refrigeration, then the required safety devices will be there to protect the occupants.

It seems foolish to attack positive pressure systems in this manner, since with the exception of their R-123 chillers, every other air conditioning product the competition sells uses a positive pressure system! Any refrigerant can be used safely or dangerously. Good equipment design, good application and proper operation and maintenance will provide an appropriate system.

There will be lots of R-123 in the future for servicing purposes

By 2030 R-123 will be phased out and after that, the only source will be from reclamation. It is commonly stated that since you (the customer) don't have trouble sourcing R-11 and R-12, you won't have trouble sourcing R-123. The big difference here is R-11 and R-12 were used in many industries for over 50 years. There were 80,000 centrifugals in the United States alone using CFCs. R-123 is only used in negative pressure chillers built since 1995. The inventory is magnitudes smaller.

Some manufacturers will "guarantee" refrigerant availability for a small charge. The customer is left thinking there is depot of refrigerant somewhere with his name on it. It is an empty promise if it does not guarantee a price. Of course there will be refrigerant available if you have enough money! Help your customers protect themselves. If they are considering entertaining bids for negative pressure chillers, recommend they add a clause to the specifications requiring a guarantee for refrigerant availability and the price. Here is an example:

"Where chillers operate on R-123, the manufacturer shall provide the owner, a written guarantee for the availability of refrigerant for the life of the equipment. The price for refrigerant will be clearly stated. If alternative refrigerants are provided, the manufacturer shall be responsible for all costs required to modify the equipment to operate appropriately with comparable capacity and performance as was originally provided."

There will be a replacement for R-123 (figure 3)

Some customers are lead astray to believe there are "drop in" replacement refrigerants for R-123. This is unfortunate because there appears to be no viable replacement for R-123. Refrigerants based on n-pentane or iso-pentane are not very likely since these refrigerants are highly flammable. Considering the large amount of refrigerant in a centrifugal chiller this would represent a potentially explosive situation. Also, since negative pressure chillers draw in air, an explosive mixture could be present within the chiller.

The closest two HFCs to R-123 are R-245ca and R-245fa. R-245ca is flammable so very little research is going into using it. R-245fa is expected to be classified as a B1 (higher toxicity – no flame propagation) refrigerant. The primary concern with R-245fa is that it operates at slightly higher pressures than R-123 requiring ASME certified construction in the chiller. This means it cannot be used as a retrofit unless the chiller was built to ASME standards initially.

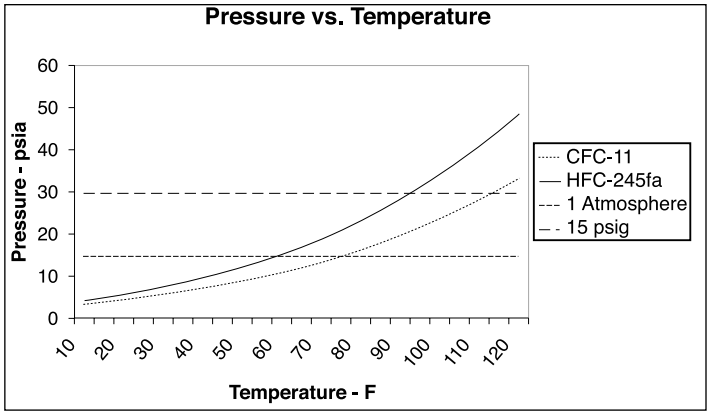
Our customers can protect themselves by specifying that chillers be ASME certified. This is a similar approach to what customers did in the 1990s when R-123 was first introduced. At that time chillers that might be retrofitted to R-123 were built with different motor insulation and seal material which was compatible with both R-11 and R-123. This allowed the owner to change refrigerants in the future without rebuilding the chiller. Most negative pressure chillers can currently be built to ASME standard. Heat recovery chillers with R-123 require ASME construction. As an added bonus, the owner gets a much higher quality control. ASME requires certified materials, fabricators and third party validation. If the customer is considering entertaining bids for negative pressure chillers, recommend they add a clause to the specifications requiring the necessary construction to use future refrigerants. Here is an example;

"Chillers that operate on R-123, will or should be compatible with R-245fa. Chillers will or should be ASME certified and bear the ASME label."

Conclusion

Our customers want a reliable air conditioning system that meets their life cycle analysis (A balance of first cost vs. operating cost). We must not lose sight of this. However, refrigerants can and will be used to "sell" one product over another. When this happens, it is important to be able to provide plain simple facts to our customers and solutions that will protect them today and in the future.

Figure 3



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