HVAC&R ENGINEERING

update

Refrigerant Solutions for Today's Environmental Challenges

Preface

The HVACR industry faces two major environmental challenges today: stratospheric ozone depletion and global climate change.

Stratospheric Ozone Depletion is believed to be caused by the release of certain manmade ozone-depleting chemicals into the atmosphere. A compromised ozone layer results in increased ultraviolet (UV)

radiation reaching the earth's surface, which can have wide ranging health effects. Legislation has been enacted worldwide through the Montreal Protocol to phase out the production of these chemicals. This phaseout is in progress, and the scientific evidence indicates repair to the ozone layer is underway.

Global Climate Change is believed to be caused by the buildup of greenhouse gases in the atmosphere. The primary greenhouse gas is carbon dioxide (CO_2), created by fossil-fuel-burning power plants. These gases trap the earth's heat, causing global warming. Legislation is not yet in place, but any policy changes or legislation will be enacted through the Kyoto Protocol.

CFC and HCFC refrigerants used by the HVACR industry are suspected ozone-depleting substances. CFC, HCFC and HFC refrigerants are considered greenhouse gases. In addition, HVACR equipment is a major power consumer. Therefore, the industry is part of these environmental challenges. This brochure updates the status of both issues and YORK International Corporation's perception of their impact on the liquid chiller market.

Worldwide Ozone Depletion Legislation

Worldwide legislation has been enacted through the United Nations Environmental Programme (UNEP) to reduce stratospheric ozone depletion. The Montreal Protocol was approved in 1987 to control the production of suspected ozone-depleting substances, among them chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), commonly used as refrigerants in the HVACR industry. The Montreal Protocol has a provision to conduct and review future scientific, technical and economic assessments, and adjust the legislation accordingly. Further evidence in the early 1990s did suggest a phaseout of ozone-depleting substances was in order. Amendments were made to the Protocol in London (1990), in Copenhagen (1992) and in Vienna (1995). No changes have been made since 1995.

CFCs, which have the highest Ozone Depletion Potential (ODP), were phased out of production on January 1, 1996. Today, the only replacement CFC refrigerants available for existing equipment are those that were stockpiled prior to 1996, or those recovered

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Montreal Protocol Production Caps		
CFCs	January 1,1996	Production ceases
HCFCs	Production caps begin January 1, 1996, based on 2.8% of CFCs used in 1989, weighted by ozone depletion potential (ODP); plus ODP-weighted 1989 HCFC consumption… thus on January 1:	
	1996	Cap (above formula)
	2004	65% of cap
	2010	35% of cap
	2015	10% of cap
	2020	0.5% of cap
	2030	Production ceases

Table-1

and recycled from retired equipment. Equipment utilizing CFCs is permitted to remain in operation.

HCFC consumption has been limited or capped at a percentage of historic usage on an ozone-depletion weighted basis, beginning in 1996. The cap will incrementally decrease and ultimately eliminate worldwide consumption in the year 2030. Percentage of ODP – not percentage of total refrigerant manufactured – is the key concept of the HCFC phasedown. Since HCFC-22 and HCFC-123 have only five and two percent ODP, respectively, of the CFCs they replace (CFC-11 = 1.0 ODP), considerably more HCFCs can be produced. The 2.8% ODP equivalent production cap of CFCs, plus the actual 1989 HCFC production, is projected to adequately cover industry demand for HCFCs during the phase-down period.

The phaseout schedule for developed countries is shown in *Table-1*. The phaseout schedule for developing countries lags by 10 years.

As alternatives to HCFCs come to market between 2004 and 2015, reductions in the production cap can be made and still allow adequate supplies for new equipment purchased with HCFCs, and to service existing equipment. No new equipment can be sold with HCFCs starting in 2020. Between 2020 and 2030 the 0.5% of cap covers a service tail of HCFC-123 for existing equipment only.

This is not to say the world can indiscriminately use HCFCs during this time period. Containment, recycling and reclamation of all refrigerants (CFCs, HCFCs and HFCs included) will be necessary to ensure adequate supplies in the future. (HFCs refers to hydrofluorocarbons.) A key provision of the Montreal Protocol allows each participating nation to establish its own regulations within the framework of the international phaseout schedule. This reflects the realization that each nation is its own best judge of which refrigerant is most important to its future. For example, the U.S. Environmental Protection Agency (US EPA) consulted with the Air-Conditioning and Refrigeration Institute (ARI), the Alliance for Responsible Atmospheric Policy (ARAP), the Association of Home Appliance Manufacturers (AHAM) and other industry groups in the U.S. to gather and arrive at a responsible policy in support of the Montreal Protocol.

US EPA Approach to Ozone Depletion Legislation

Based on environmental and industry needs, the US EPA went to the 1992 Copenhagen Meeting with a multi-step phaseout plan for HCFCs. The basic idea was to keep HCFC-22 available for new equipment through 2010, and for maintenance and service purposes through 2020. HCFC-123 would be available for new equipment through 2020, and through 2030 for service needs. HCFC-141b and HCFC-142b (used for foam insulation) have separate, quicker phaseouts. The phaseout schedule is based on each refrigerant's ODP: the higher the ODP, the faster the phaseout. See *Table-2* for details.

The incremental phaseout of HCFCs is good news: it underscores the critical role of HCFCs in effecting the transition from CFCs, while providing the HVACR and chemical industries time to develop the next generation of refrigerants. A case in point is large tonnage centrifugal chillers. Prior to the Montreal Protocol, they primarily utilized CFCs, and acceptable alternative refrigerants had to be quickly developed to replace them, both for retrofit and for new replacement chillers. Most centrifugal chillers utilized CFC-11, and the only alternative appeared to be HCFC-123, which was not yet on the market. The other centrifugal refrigerants were CFC-12, CFC-500 and HCFC-22. The replacement for the CFC-12 and CFC-500 was HFC-134a, also not yet available. Today, all centrifugal chillers utilize HCFCs or HFCs.

Smaller DX chillers and packaged unitary air conditioners used predominantly HCFC-22, and still do today. The alternative refrigerants to HCFC-22 were not as easy to determine or develop. There was not just one replacement, but many replacements for HCFC-22, depending on the application. But progress is being made, and new DX chillers using HFC-407C, HFC-410A and HFC-134a are now entering the market to replace HCFC-22. The incremental phaseout of HCFCs was a necessary step to make a smooth transition from CFCs to more environmentally friendly refrigerants. HCFC technology has been a cornerstone of our industry and a solid bridge to environmentally sound cooling technology.

During this changeover from CFCs to HCFCs and HFCs, the US EPA created the Significant New Alternatives Policy (SNAP) Program under the U.S. Clean Air Act. SNAP evaluates the alternatives to ozone-depleting substances on the basis of ozone-depletion potential, global warming potential, toxicity, flammability, exposure and equipment applications. The SNAP-approved refrigerants to replace CFCs, which were primarily utilized in centrifugal chillers, are shown in *Table-3*. The SNAP-approved refrigerants that replace HCFCs are discussed later.

Effect of the CFC and HCFC Phaseout on the HVACR Industry

The Montreal Protocol established firm and responsible phaseout schedules for CFCs and HCFCs. This is good news for the environment, because it has hastened the transition from CFCs, which pose the greatest threat to stratospheric ozone. It is also good news for the HVACR industry, because it allows the continued and even expanded use of HCFCs, with assurance of service replacement refrigerant for the normal life of the equipment.

Without the continued supply of HCFCs, the industry could not have hastened the phaseout of CFCs so dramatically. The phaseout never would have been possible without the widespread availability of HCFCs to replace CFCs in new equipment.

Progress of Conversion and Replacement of CFC Chillers

Year	Conversions	Replacements	Total to Date	% Converted
Before 2000	7,024	24,492	31,516	39
2000	517	3,271	35,304	44
2001	507	3,359	39,170	49
2002	488	3,765	43,423	54

Source: The Air-Conditioning and Refrigeration Institute (ARI)

Regarding CFCs, the phaseout has encouraged equipment owners to develop and implement a refrigerant plan to conserve their existing refrigerant by repairing leaks; to provide better maintenance of equipment to prevent future leaks; to retrofit with alternative refrigerants; and to replace CFC chillers with new chillers utilizing HCFC and HFC refrigerants, as shown above in ARI tabulation.

Regarding HCFCs, there is broad industry consensus that a workable phase-down schedule is in place for HCFC refrigerants. In large tonnage chiller applications, this means that HCFC-22 and HCFC-123 remain viable choices for retrofit, replacement and new chiller purchases. For DX chillers, it gives the manufacturers the time to develop new systems using some of the new blend refrigerants to replace HCFC-22. When HCFCs are phased out of production in new equipment, we are assured of adequate HCFC supplies for maintenance and service to support that equipment throughout their life expectancy.

US EPA Phaseout Schedule for HCFCs

Specific HCFC	ODP	End Use In New Equipment	End Use For Service	Total Production Phaseout
141b	0.10	NA	NA	2003
142b	0.07	NA	NA	2010
22	0.05	2010	2020	2020
123	0.02	2020	2030	2030

Table-2

SNAP Approved Refrigerants For Centrifugal Chillers

Existing CFC Centrifugal Chiller	Acceptable Refrigerants	
	For Retrofit of CFC Chillers	In New Centrifugal Chillers
CFC-11	HCFC-123	HFC-134a, HCFC-123 HCFC-22
CFC-12	HFC-134a	
CFC-500	HFC-134a	

Table-3

Evaluating the Leading Halocarbon Refrigerants

The five halocarbon refrigerants shown in *Table-4* are the leading choices for commercial / industrial chiller applications. They are widely available and are acceptable alternatives to CFCs. All are recognized by the three Model Building Codes in the United States. None of these refrigerants are perfect from an environmental viewpoint, but all of them are significantly better than the CFCs they replace. YORK International supports the use of all five refrigerants, with selection criteria matched to the specific application. Here's how they compare.

Alternative Halocarbon Refrigerants For Water Chillers

Refrigerant	Centrifugal Chiller	DX Chiller
HCFC-123	X	
HFC-134a	X	X
HCFC-22	X	X
HFC-407C		X
HFC-410A		X

Table-4

HCFC-123 is a low-pressure refrigerant used in centrifugal chillers. It is a high-efficiency refrigerant with an ODP of 0.02. This has been extremely good news for the owners of CFC-11 chillers, because HCFC-123 is the only alternative refrigerant available, should these machines require conversion or retrofit in the future.

The Montreal Protocol and the US EPA's supporting policy make HCFC-123 a viable refrigerant for new, retrofit and replacement chiller applications through the early part of the 21st century, with adequate production of replacement refrigerant through 2030. Recycled HCFC-123 will be available well beyond 2030.

All of the earlier technical issues related to the application of HCFC-123 have been successfully resolved, including materials compatibility (both new and retrofit) and toxicity and safety concerns.

YORK International introduced the industry's first HCFC-123 centrifugal chiller in 1989, and has performed a large number of field conversions from CFC-11 to HCFC-123 since that time. The available scientific evidence, as well as our own extensive laboratory and field experience, indicate that HCFC-123 is a safe, effective refrigerant. Every installation monitored has operated well below the allowable time-weighted exposure limit of 50 parts per million (PPM). In fact, ambient levels have typically been less than 0.6 PPM during routine maintenance and refrigerant transfers. HCFC-123 has been assigned the ASHRAE Safety Group Classification of B1.

Consequently, YORK continues to recommend, sell and service chillers charged with HCFC-123; and encourages owners of existing CFC-11 systems to consider HCFC-123 as a suitable refrigerant for retrofit and replacement applications. Further, we will provide comprehensive service on any HCFC-123 chiller system, regardless of brand or owner's prior service-company relationship.

HCFC-123 is the most efficient non-CFC refrigerant available today for lower capacity centrifugal chillers. YORK manufactures a full line of HCFC-123 chillers, from 150 to 850 tons.

HFC-134a is a medium-pressure refrigerant having an ODP of zero. As such, it is a long-term environmental solution to ozone depletion and is not scheduled for production phaseout. HFC-134a has a low toxicity level and has been assigned the ASHRAE Safety Group Classification of A1.

This high-efficiency refrigerant is the only non-HCFC refrigerant available today for centrifugal chillers and has been well received for this application. HFC-134a has also proven to be effective in retrofitting existing gear drive CFC-12 and CFC-500 centrifugal chillers. A gear change can often obtain near-original performance.

YORK manufactures a full line of high efficiency HFC-134a chillers, from 350 to 5,500 tons.

HFC-134a can be utilized in chillers with positive displacement compressors as well, especially in water-cooled, flooded evaporator chillers where compressors and heat exchanger combinations can be mix-matched and optimized for the refrigerant.

Table-4 shows several choices for refrigerants for DX chillers that use positive displacement compressors. Enough differences exist between each of them that one refrigerant would not be the likely choice for all chillers. Each manufacturer will determine which refrigerant makes the most sense for its product line.

The fact that HFC-134a requires about 35% more volumetric capacity on the compressor usually results in substantial derate, when used as a drop-in replacement for HCFC-22.

HCFC-22, introduced nearly 60 years ago, has been the workhorse of the air conditioning and refrigeration industry, not only in chillers, but in smaller residential and commercial unitary equipment as well. It remains the predominant refrigerant in use today and continues to be specified. Expanded use of HCFC-22 is the major reason the industry has been able to reduce its CFC usage in large chillers during this time period. Although its relative low cost and high efficiency make it attractive, HCFC-22 has a slightly higher ODP value (0.05) than HCFC-123 (0.02), and that is the basis for its earlier phaseout. HCFC-22 has a low toxicity level and has been assigned the ASHRAE Safety Group Classification of A1.

U.S. EPA's phaseout schedule for HCFC-22 has allowed refrigerant manufacturers time to develop and test suitable replacements, particularly for positive displacement compressors. These new refrigerants are becoming available, and the equipment manufacturers are completing their development and testing. On balance, the Montreal Protocol and the US EPA schedule for phaseout support HCFC-22 as a viable refrigerant today, with adequate production of replacement refrigerant through 2020. Recycled HCFC-22 will continue to be available after that time.

YORK manufactures a full line of HCFC-22 water-cooled chillers utilizing centrifugal, screw and reciprocating compressors, as well as air-cooled chillers using screw, reciprocating and scroll compressors.

HFC-407C is a high-pressure refrigerant, similar to HCFC-22, and has an ODP of zero. As such, it is a long-term environmental solution to ozone depletion and is not scheduled for production phaseout. HFC-407C is a blend refrigerant with a low toxicity level. It has been assigned the ASHRAE Safety Group Classification of A1/A1.

In selecting a refrigerant to replace HCFC-22, YORK found HFC-407C to be an ideal alternative for air-cooled DX chillers. Its operating characteristics are so similar to HCFC-22 that it has been used as a drop-in alternative in machines originally designed for HCFC-22. This allows the continued use of the proven design and components of YORK's air-cooled chillers. Additionally, a unique feature of HFC-407C – the property known as "temperature glide" – presents intriguing implications for DX chiller design. This temperature glide phenomenon, when matched with DX cooler design modifications, can improve energy efficiency input.

HFC-407C is a blend of three refrigerants: HFC-32, HFC-125 and HFC-134a. This composition exhibits the characteristics of a zeotropic blend, meaning that the resulting mixture does not act as a single substance. At a given pressure, it evaporates over a range of temperatures, rather than at a single temperature. Thus, the term, temperature glide.

HFC-407C has a temperature glide of approximately 8°F, which can be leveraged to give opportunities for greater operating efficiency. If the DX evaporator is designed as a counterflow heat exchanger, refrigerant and water enter at opposite ends, and the leaving refrigerant temperature can be greater than the leaving chilled water temperature as shown in *Figure-1*. The higher leaving refrigerant temperature means the compressor does less work, resulting in lower power consumption. The counterflow heat transfer technology, coupled with the addition of a state-of-the-art Suction Line Heat Exchanger (SLHX), allows the chiller to fully exploit the temperature glide properties of HFC-407C.

YORK manufactures a full line of air-cooled chillers utilizing this HFC-407C technology, from 10 to 400 tons. They are the highest efficiency chillers on the market today.

Although not utilized in chillers today, ***HFC-410A*** is mentioned because there is much discussion about it. HFC-410A is an approved alternative to HCFC-22 in new DX chillers. It is a high-pressure refrigerant, having approximately 40% higher pressure than HCFC-22. As a result, it can provide

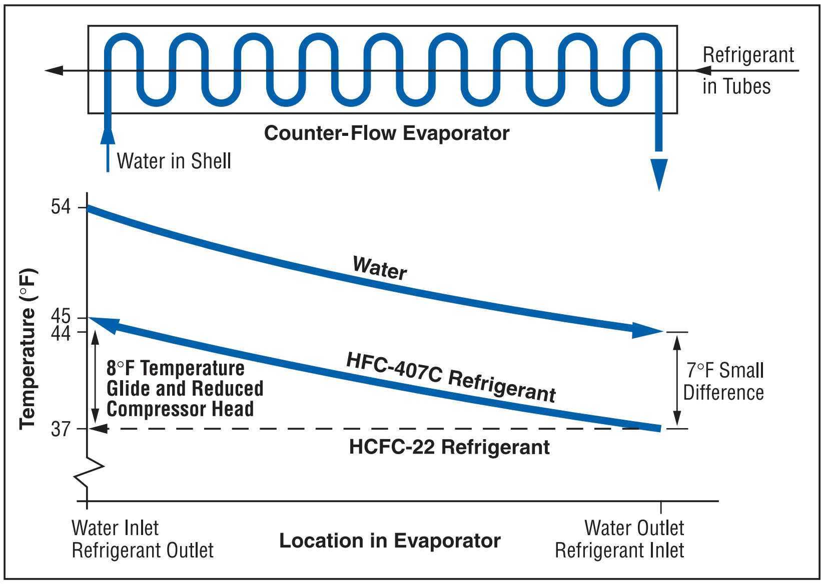


Figure-1 – HFC-407C Temperatures in a Counter-Flow Evaporator

significant capacity gain to a compressor designed to handle the pressure. HFC-410A is a leading candidate for unitary residential and commercial equipment.

HFC-410A is a blend refrigerant consisting of HFC-125 and HFC-32. It has a low temperature glide of 1°F, small enough to have little or no effect on heat exchanger performance. HFC-410A has an ODP of zero. As such, it is a long-term environmental solution to ozone depletion and is not scheduled for production phaseout. HFC-410A has a low toxicity level and has been assigned the ASHRAE Safety Group Classification of A1/A1.

YORK's Position on Refrigerants for Chillers

YORK International Corporation supports both the Montreal Protocol and the US EPA position on refrigerants. We support the HVACR marketplace with equipment utilizing HCFC and HFC refrigerants in commercial/industrial packaged water chillers; as well as absorption chillers utilizing water/saline solution as the refrigerant; and refrigeration equipment (including chillers) utilizing ammonia and hydrocarbon refrigerants.

With more widespread availability of HFCs, the transition away from HCFC refrigerants has started. This is especially true in positive displacement (screw, scroll and reciprocating) compressors that historically used HCFC-22. For these applications, YORK encourages customers to specify the use of an HFC, rather than insist on a specific refrigerant. This will allow manufacturers to offer equipment utilizing all the HCFC alternatives (HFC-407C, HFC-410A and HFC-134a). A single refrigerant will not replace HCFC-22 in all chiller technologies. Meanwhile, each HFC refrigerant provides unique benefits for specific applications, with multiple sources for the user.

YORK offers equipment utilizing all commercially viable refrigerants, without preference for a specific refrigerant technology. This has always been our approach to the CFC issue and continues to be the basis for our product development programs. Thus, ***YORK offers the industry's widest selection of chillers over the broadest tonnage range using all the viable refrigerants.***

Global Climate Change: Legislation to Reduce Global Warming

To date, the environmental legislation has dealt solely with stratospheric ozone depletion. The issue of global climate change is an emerging issue. The United Nations Environmental Programme (UNEP) convened meetings in Rio de Janeiro (1992) and Kyoto (1997), resulting in the Kyoto Protocol. These meetings have not resulted in definitive legislation, just broad outlines to reduce global warming based on reduced emissions of greenhouse gases. Continual assessments of the scientific evidence is being conducted, and future meetings will likely result in legislation to reduce global warming.

A recent brochure published by the US EPA on this subject said: "Human activities are adding greenhouse gases – pollutants that trap in Earth's heat – to the atmosphere at a faster rate than at any time over the past several thousand years. A warming trend has been recorded since the late 19th century, with the most rapid warming occurring in the past two decades. If emissions of greenhouse gases continue unabated, scientists say we may change global temperature and our planet's climate at an unprecedented rate for our society."

These greenhouse gases are primarily carbon dioxide, methane and nitrous oxide. Scientists generally believe that the combustion of fossil fuels is the main reason for the increased concentration of carbon dioxide. This is attributed to cars and trucks, and to power plants generating electricity for industry, businesses and homes. As a large user of electricity, the HVACR industry is again at the forefront of any future legislation on global climate change.

Recent meetings of UNEP no longer discuss ozone depletion and climate change as two separate issues. It is likely that future legislation will be mutually supportive and coordinated between the Montreal Protocol and the Kyoto Protocol.

As with Ozone Depletion Potential, each of the refrigerants in question (CFCs, HCFCs and HFCs) has a Global Warming Potential (GWP) associated with it. But global climate change is more complex, since it has both direct and indirect effects. The GWP is a measure of the refrigerant's direct effect, just like ODP — the refrigerant's potential to add directly to global warming when released to the atmosphere.

The indirect effect has to do with the efficiency of the equipment it is used in. The more efficient the chiller, for example, the less energy required to operate it, and the less carbon dioxide (CO_2) emitted to the atmosphere by fossil-fuel power generating plants.

Global Warming Potential

The GWP shown in *Table-5* represents how much a given mass of a chemical directly contributes to global warming over a 100-year time period compared to carbon dioxide. Carbon dioxide's GWP is set at 1.0. As with ODP, if a refrigerant is not emitted to the atmosphere, there is no direct effect to the environment. This realization has produced legislation in the United States and elsewhere prohibiting the intentional release of refrigerants to the atmosphere and requiring the reclamation of used refrigerants and the repair of major equipment leaks. Equipment manufacturers have also responded by designing and manufacturing tighter new equipment and retrofitting kits to prevent leakage in existing equipment. Although these actions were initiated to reduce ozone depletion, they apply equally to global warming.

The current science of global climate change suggests that the direct effect, or GWP, has a minor effect on total global warming compared to the indirect effect. Ninety-eight percent of total global warming attributed to chillers is thought to be caused by the indirect effect.

Global Warming Potential (GWP)	
Refrigerant	**GWP (100 years)**
HCFC-123	93
HFC-134a	1300
HCFC-22	1700
HFC-407C	1600
HFC-410a	1890

Table-5

Indirect Effect

As previously mentioned, a refrigerant's indirect effect has everything to do with the equipment's energy efficiency. The higher the equipment's efficiency, the less the contribution to global warming. This is not the chiller's full load design efficiency, but is a measure of the total kWh consumed. A chiller typically operates only 1-2% of the time at design. It operates the other 98-99% of the time at off-design conditions.

Selecting equipment with the lowest overall energy consumption will do the most to reduce global warming. Water-cooled chillers capable of operating with low cooling tower water temperature, naturally available during the off-season, and variable speed drives will favorably impact energy reduction and therefore, global warming.

What Is YORK International Doing to Reduce Ozone Depletion and Global Warming?

The solution to stratospheric ozone depletion is to move away from the use of ozone-depleting substances, and to minimize the release of these chemicals to the atmosphere.

YORK International, an early supporter of the Montreal Protocol, continues to lead the industry in moving away from CFCs, to interim HCFCs and, finally, to HFCs in vapor compression chillers. We also have developed chiller systems using zero-ODP alternatives to halocarbon refrigerants. These include vapor-compression chillers using ammonia as refrigerant and absorption chillers using water. Today, YORK offers equipment utilizing all commercially viable refrigerants, without preference for a specific refrigerant technology. Additionally, our chillers utilize the latest technology to prevent leaks.

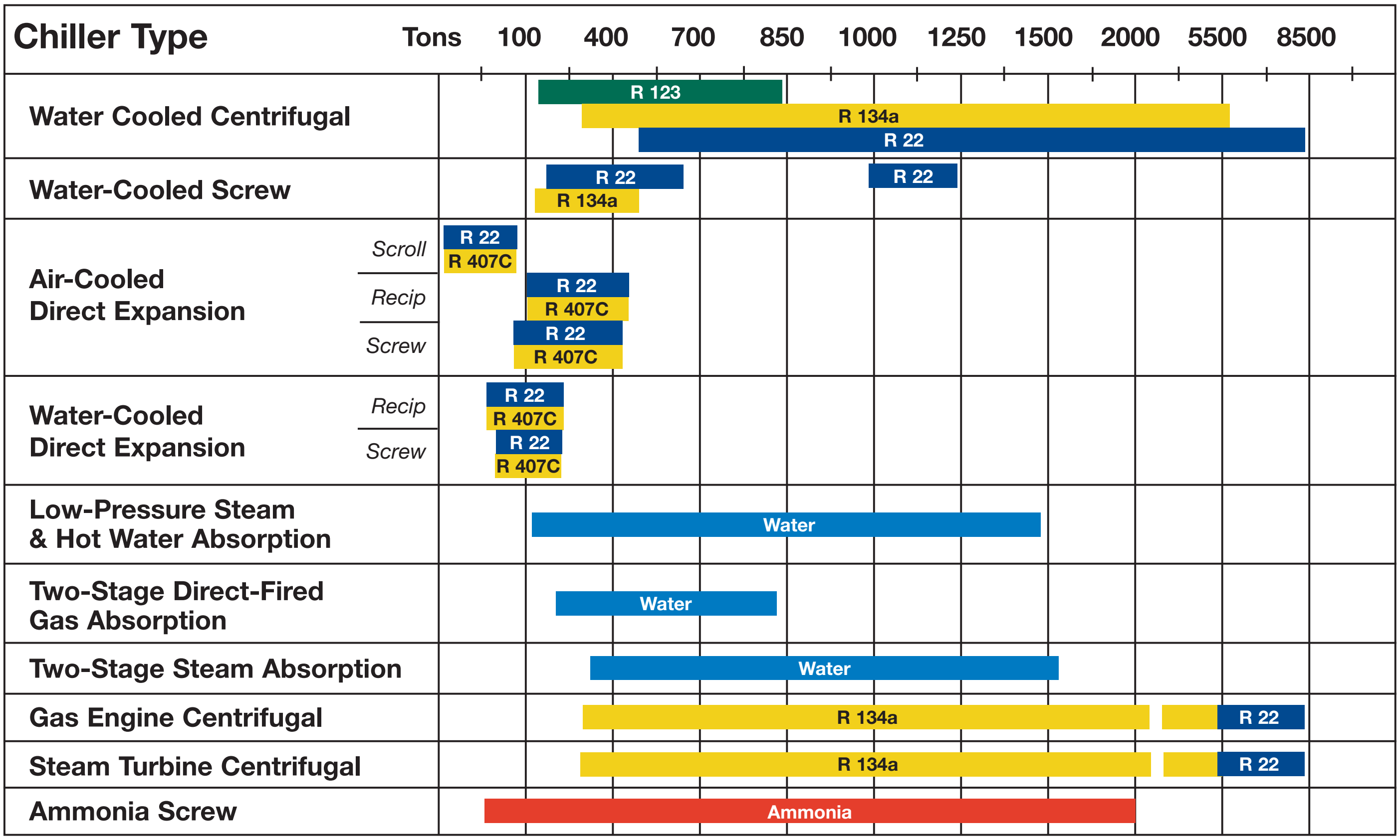
The solution to the reduction in global climate change, as we know it today, is to minimize the energy consumption of equipment and to minimize the release of greenhouse gases to the atmosphere.

YORK's new leak-tight chiller designs, developed in the name of ozone depletion, have also paid dividends for reduction in global warming. If the refrigerant does not leave the chiller, its ODP and GWP are zero. Today's tight systems will provide a very low ODP and GWP.

In this same time period, YORK has led the chiller industry in energy efficiency. Most noteworthy are our variable-speed drive centrifugal chillers, which provide the lowest year-round energy consumption of any chiller on the market, and our new air-cooled screw chillers using HFC-407C, providing the highest COP of any comparable chiller. The most energy-efficient equipment will have the most positive impact on global climate change.

YORK also developed hybrid centrifugal chillers utilizing gas engines and steam turbines to drive the compressor. These are particularly attractive where electricity is in

YORK Millennium Chiller Choices



short supply and gas or steam is readily available. And from a global warming perspective, using a non-electric drive further reduces CO_2 emissions.

In summary, YORK International offers the industry's widest range of non-CFC chillers and the most energy-efficient chiller technology utilizing electric and non-electric drives to minimize ozone depletion and global warming. We've made a firm commitment to provide the most environmentally friendly chiller technology for every application and to meet every customer preference.

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