DRAFT Industrial Decarbonization Product Guide

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Overview

This document is an exploration of industrial heating and cooling systems with an emphasis on low global warming potential refrigerants for cooling solutions and high temperature heat pumps for heating solutions. Universally used industrial equipment has been categorized by common and high impact industries. Common manufacturing industries are used as a guide to present the variety equipment needed in industrial processes.

Introduction

Industrial vapor compression systems serve a wide range of applications dependent on the heating and cooling needs of a building. This guide is an assembly of products and case studies for industrial systems. Vapor compression systems use refrigerants to transfer heat between a hot and cold reservoir. Air conditioners, chillers, refrigeration, and heat pumps are examples of vapor compression systems. In large scale systems for industrial application this mechanical equipment utilizes various refrigerants for their thermodynamic properties to reach extreme high and low temperatures. The table below illustrates the capability of heat pump technology to produce the temperatures required for many industrial processes. [2] Climate action plans and policy require low global warming potential refrigerants which fazes out many common refrigerants with high GWP.

Useful Resources:

Accelerate Magazine
(2015) Guide to Natural Refrigerants in North America – State of the Industry:
http://publication.shecco.com/upload/file/org/1442485610258468_36393.pdf

Energy Efficiency Conservancy Authority
Alternative Technologies for Process Heat: for the New Zealand Government:
https://genless.govt.nz/assets/Business-Resources/International-technology-scan.pdf

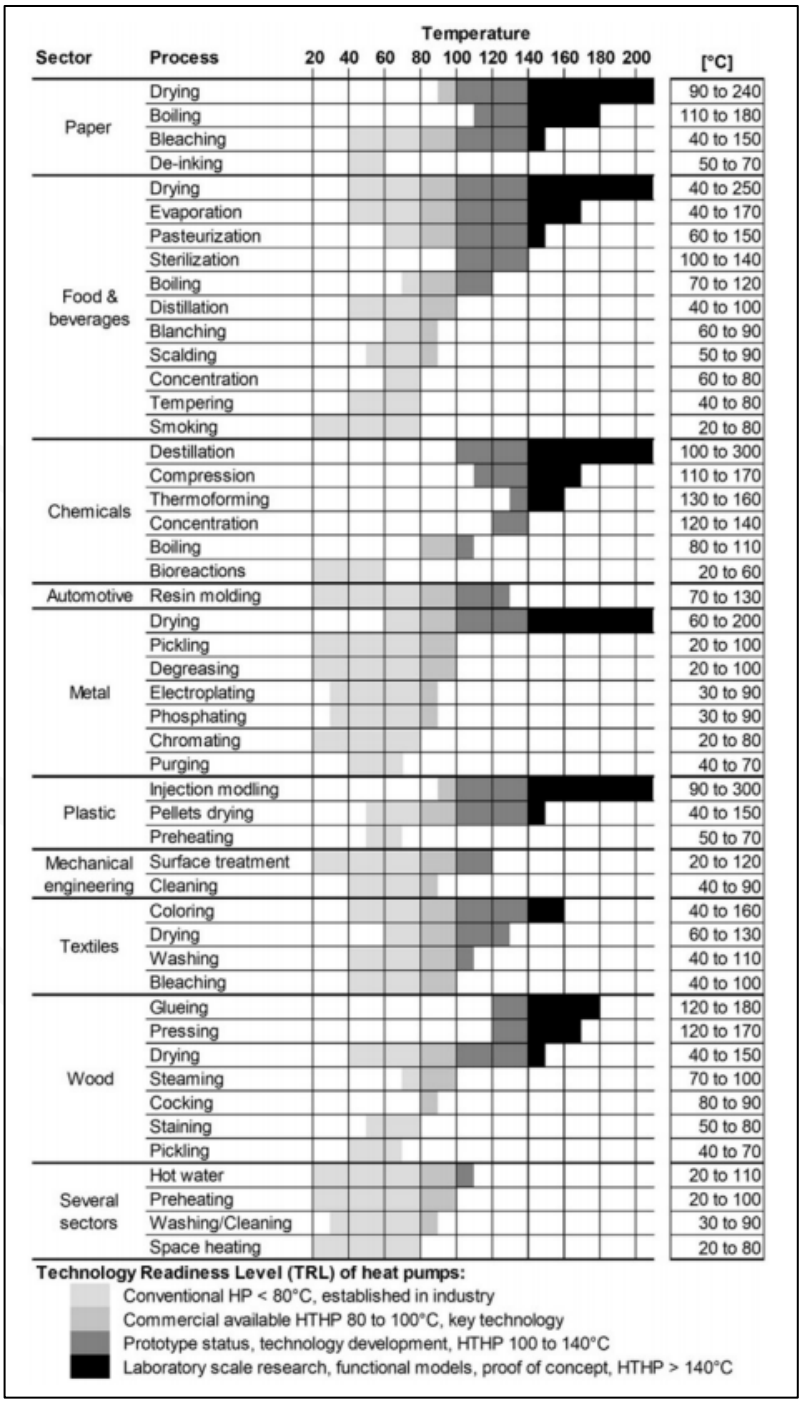

Figure 1: Heat pump temperatures for industrial processes and technology readiness level.[1]

Decarbonization of Industrial Processes Case Studies

HYBRID ENERGY[3]

Arla Arinco - Videbæk, Denmark: Each year dry milk production was costing Arla Arinco, a company in the dairy product manufacturing industry, massive amounts of energy. Thus, prompting the installation of a 1,200 kW Hybrid Energy Heat Pump that uses the natural refrigerants R-718 and R-717 (Water & Ammonia) with a maximum sink temperature of 185 °F. It recovers waste heat from the evaporation process and utilizes it to heat up the process air rather than cooling the cooling the evaporator with water from cooling towers. This improvement in efficiency provides a repayment period of 20 months and saves the user approximately 1,400 metric tons of CO2 emissions and 4.6 GWh of energy annually.

GEA[4]

Mars Wrigley Inc. - Veghel, Netherlands: Mars Wrigley Confectionery, a manufacturer in confectionary goods contracted GEA to further the energy savings and CO2 reduction by installing a customized heat pump system that would significantly enhance their energy efficiency. The custom heat pump is based on the GEA V HP reciprocating compressors — which make it possible to extract and boost what would otherwise be unusable low-temperature heat from the refrigeration units — and using it to heat water up to 63°C. This water is than cycled through the rooftop warm water piping network that was specially installed which and then used for various other processes in the plant such as air handling units. With a maximum sink temperature of 145.4°F, this heat pump has reduced total energy consumption across the plant 6% and contributed to the reduction of 1,000,000 m3 of natural gas per year which is equivalent to more than 1,000 t CO2 per year.

Emerson Climate Technologies[5]

Emerson Climate Technologies (ECT) was contracted to create and implement a heat pump system in an Iowa food processing plant capable of capturing the rejected heat of the plant's boiler stack system in order to be used to provide water heating and substantially increase energy savings. ECT began their design by creating a system utilizing ammonia due to the plant's preexisting ammonia refrigeration system. A challenge presented to ECT is the plant's requirement to have wash down water classified as a potable supply in accordance to local codes prohibiting ammonia to be in direct heat exchange with ammonia. The system implemented in the food processing plant delivers hot water up to 145°F at 170 GPM. It utilizes Vilter™ single screw compressors allow for the inherent high pressure without a loss efficiency. Over the course of the year the heat pump is estimated to provide an average year-round heating capacity of 7.013 MMBtuh. The ECT ammonia heat pump saves $250,000 each year and saves fourteen million gallons of water per year because of the reduced load on the evaporative condensers.

ENGIE, GreenPAC Hybrid Heat Pump[6]

ENGIE has innovated a hybrid heat pump, GreenPAC, to operate at the high temperature of 248°F utilizing only natural refrigerant, ammonia and water. These heat pumps are classified as hybrids because they combine compression and absorption technologies. Every product is customized to the client's needs. Additionally, each product also includes a high energy performance ratio up to 6. The hybrid heat pump is also advantageous for users because it has the ability to operate at lower pressure than standard heat pumps, 20 bar instead of the typical 35. Some applications may include washing, pasteurization, CIP, process heat, and general heating.

Global Warming Potential of Refrigerants

Heat pumps can move heat from one substance to another so well because of the compression and expansion of chemicals called refrigerants. There are many types of refrigerants, but the most common for heating and cooling are the Hydrofluorocarbons R410A and R134a which are considered replacements for refrigerants that are Ozone depleting substance (ODS) like R22. R410A and R134a do not contribute to ozone depletion but they do have a higher GWP. To rectify this issue the industry has been moving toward "natural" refrigerants like Ammonia (R717), CO_2(R744), and Propane (R290) that do not deplete the ozone and have a low global warming potential (GWP).[7] GWPs listed are IPCC AR4 (2007), 100-year GWPs. A GWP value greater than 124 is considered "HIGH" by the California Air Resources board.[8]

Refrigerant Name	formula	CAS name	Global Warming Potential (GWP)*	Ozone depleting substance (ODS)	Kind
R-717	NH3	Ammonia	0	NO	Natural Refrigerant
R-718	H2O	Water	0	NO	
R-744	CO2	Carbon dioxide	1	NO	
R-290	C3H8	Propane	4	NO	
R-600a	C4H10	Isobutane	5	NO	
R-1270	C3H6	Propylene	1.8	NO	
R-1234yf	C3H2F4	Opteon YF or Solstice YF	1>	NO	HFO
R-32	CH2F2	Difluoromethane	675	NO	HFC
R-245fa	CF3CH2CHF2	1,1,1,3,3-Pentafluoropropane	1030	NO	HFC
R-134a	CH2FCF3	1,1,1,2-Tetrafluoroethane	1430	NO	HFC
R-407C		R-32/R-125/R-134a (23/25/52)	1774	NO	HFC mix
R-410A	Puron, AZ-20	R-32/R-125 (50/50)	2088	NO	near-azeotropic mixture
R-404A	HFC-404A	Pentafluoroethane, 1,1,1-Tetrafluoroethane, 1,1,1,2-Tetrafluoroethane	3992	NO	near-azeotropic mixture
R-2					
R124					
R151					
R133					
R-123					
R-22	CHClF2 Freon	Chlorodifluoromethane	1810	YES	HCFC: Banned
R-12	CCl2F2 Freon	Trichlorodifluoromethane	10910	YES	HCFC: Banned

Climate Action Policy

Refrigerants started to be regulated when ozone depletion was realized. The Montreal Protocol was meant to target CFC's and HCFC's and was created in 1987, then amended in 2016 to include HFC's. The U.S. has agreed to the Montreal Protocol but has not yet ratified the previously mentioned Kigal amendment. In the U.S., the EPA is the primary regulatory agency concerned with refrigerants. The Significant New Alternatives Program (SNAP) rules 20 and 21 was enacted during the initial Montreal Protocol. The EPA was then sued and lost, limiting their ability to regulate high-GWP HFC's. The EPA also regulated CFC's and HCFC's under Section 608 of the Clean Air Act. Due to a lack of action by the U.S. federal government 24 states have formed the U.S. Climate Alliance in response to the Paris Climate Agreement. Refrigerant policy is moving towards banning all high GWP refrigerants for new products.

Refrigeration

Product	Nor-Lake® Scientific GPR723SSS/0[9] 	MoTak MSD-2DR-BAL[10] 
Description	General Purpose Laboratory Stainless Steel Refrigerator (Medical Refrigerator)	Two Section Reach in Refrigerator.
Temp. Range (F)	33.8º to 50º	33º to 41º
Refrigerant	R290	R290
COP	—	—

Chillers

Product	**Alfa Laval**[11] Arctigo LSV Industrial Cooler 	**Cold Shot Chillers**[12] Stationary Air Cooled Chiller ACWC-24-QST 	**GEA** [13] Galaxy Series Ammonia Chiller G800 800GLX 	**Magnitude® WME centrifugal chiller by Daikin**[14] 	**Alfa-V ACV/ANV/VXD** [15]
Max Sink Temp	79.7	50	42		R-717: 97 R-744:160
Refrigerant	Water	R410a	R-717 (Ammonia)	R-134A	R-717 or R-744
Heating Capacity	1.10	24	14.28		

Dryers

Product	**GEA Ammonia Dryer**[16] 	**Tolon Tumble Dryer 90lb**[17] 	**TS Series Drying Cabinet**[18] 	**Gruenberg Granulation Dryers**[19] 	**CHA Series Heat-Les™**[20] - Heat-Les Desiccant Air Dryers 
Technology	Heat Pump	Electric Resistance	Electric Resistance	Electric Resistance	Heatless Desiccant Air Dryer
Description	The ammonia dryer removes water from the refrigerant cycles without having the machines shut down.		Use in Drycleaners, Wet cleaners, Theaters, Ski Resorts, Daycare Centers	Suitable for use in dehydrogenation applications. Serves the medical device industry.	
Temp. Range (F)	—	—	Maximum: 195ºF	Maximum: 185°F Dryer Uniformity of ±2° at 50°C (122°F)	—

High Temperature Heat Pumps

Product	**Sunchi Energy**[21] Industrial 90ºC high temperature heat pump water heater 	**Mitsubishi**[22] Centrifugal Heat Pump ETW Series 	**Johnson Controls**[23] Sabroe HeatPAC™ HPX 	**Star Refrigeration**[24] Air Source Neatpump Bespoke Condensing Unit 
Descriptions	can meet the heating demand of agricultural and beverage processing industry, electroplating drying industry, etc.	disinfection and washing can be widely found in factories, plants, etc.	ideal for sterilization, pasteurization and many other heating processes	Provides hot water and heating to all buildings on the base. extracts heat from seawater in Ramsund's harbor
Max Sink Temp	194	194	194	194
Refrigerant	R-410a (first stage), R-134a (second stage)	R-134a	R-717 (Ammonia)	R-717 (Ammonia)
Heating Capacity(BTU/hr)	0.068	1.86	2.22	1.71
Water Temp (F)[25]	131ºF to 194ºF	50ºF to 194ºF	194ºF	140º to 154º
COP	3.2	3.7	4.0	2.7

Product	**Combitherm**[26] HWW 245fa 	**Mayekawa**[27] Eco Sirocco Co2 Eco Cute Animo 	**GEA Refrigeration**[28] GEA Grasso FX P 63 bar 	**GEA RedAstrum**[29] standard ammonia screw compressor heat pump 
Max Sink Temp. (F)	248	248	194	
Refrigerant	R245fa	R-744 (Carbon dioxide)	R717 (NH3)	R-717 (Ammonia)
Heating Capacity (MBTUh)	0.86	0.30	6.8-15.3	9.90
Water Temperature (F)				131ºF to 176ºF
COP	5.34	3.1	EER: 2.72-5.6	

Resources

1 https://genless.govt.nz/assets/Business-Resources/International-technology-scan.pdf
2 https://9899f372-1a9a-47d0-9e7a-0ddf175d3d60.filesusr.com/ugd/8099df_126e9be50f8044aca439931af05bf952.pdf
3 Hybrid Energy Arla Arinco
4 GEA Mars Inc
5 Emerson Case Study Iowa
6 GreenPAC
7 Accelerate Magazine. (2015). Guide to Natural Refrigerants in North America, the State of the Industry. http://www.r744.com/files/1811_Guide_america_2015_online-compressed.pdf
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