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December 13, 2019

Richie Kaur
California Air Resources Board
1001 I Street
PO Box 2815
Sacramento, CA 95812
(Submitted via email to **richie.kaur@arb.ca.gov**)

Re: AHRI Letter Responding to CARB's Request for Input and Clarifications Following the August 6, 2019 Public Meeting for Industrial Process Refrigeration and Transport Refrigeration Equipment

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Dear Ms. Kaur,

On August 6, 2019, AHRI submitted a letter to California Air Resources Board (CARB) regarding GWP levels and feedback from original equipment manufacturers (OEMs) of stationary commercial refrigeration equipment in response to CARB-proposed regulations. On September 20, 2019, AHRI submitted comments with additional input and clarification to the August 6th letter stating that further information would be provided regarding industrial process refrigeration equipment. This comment letter describes the position of AHRI member manufacturers of industrial process refrigeration equipment with respect to CARB's latest proposed regulation. Also included in this letter is a proposal for transport refrigeration equipment in response to CARB's inquiry at the August 6th public meeting.

AHRI is the trade association representing manufacturers of heating, cooling, water heating, and refrigeration equipment. More than 300 members strong, AHRI is an internationally recognized advocate for the industry, and develops standards for, and certifies the performance of many of the products manufactured by our members. In North America, the annual output of the HVACR and water heating industry is worth more than $44 billion. In the United States alone, the HVACR and water heating industry supports 1.3 million jobs and $256 billion in economic activity.

In this letter AHRI addresses the following topics:

1. Definitions
2. Industrial Process Refrigeration Technical Justification
3. Transport Refrigeration
4. AHRI's Proposal Table
5. Exemption Clause

1. DEFINITIONS

AHRI has drafted a definition for "Industrial Process Refrigeration" equipment and "Refrigeration Chillers" based off the U.S. Environmental Protection Agency (EPA) definitions for CARB's consideration. Also provided is the EPA definition for "Refrigerated Transport." Each of these definitions are shown below for CARB's consideration.

Refrigeration Chillers

Refrigeration chillers typically cool water or aqueous glycol solutions, which is then circulated and used for needs other than comfort cooling. Chillers can be classified by compressor type, including centrifugal and positive displacement. Chillers used to cool industrial processes are discussed under Industrial Process Refrigeration.

Industrial Process Refrigeration (IPR)

Industrial process refrigeration systems add or remove heat to process streams in industrial applications and include refrigeration equipment used, for example, in the chemical, pharmaceutical, petrochemical, and manufacturing industries.

A subset of this sector generally referred to as Industrial Refrigeration includes food and beverage cooling and freezing used in the processing, preservation and storage of foodstuffs. This could include meat packing plants, vegetable and fruit freezing and cooling, cold storage warehouses with refrigerant charge over 300 lbs., industrial ice machines, and any facility where larger and often customized equipment is used to provide refrigeration for other than comfort cooling.

IPR systems often involve multiple evaporating temperatures in the same system, unlike chillers which will have one evaporating temperature. This requires one refrigerant capable of use at the lowest required temperature level, or multiple refrigerants in the same facility. This impacts the refrigerant choice because the refrigerant must be suitable for the LOWEST evaporating temperature used in the system.

Refrigerated Transport– Truck and Trailer TRUs

Refrigerated trucks and trailers covers a subset of on-road vehicles, i.e., refrigerated trucks and trailers with a separate autonomous refrigeration unit with the condenser typically located at the front of a refrigerated trailer. This end-use category also covers domestic trailer refrigeration units that contain an integrated motor (i.e., does not require a separate electrical power system or separate generator set to operate) that are transported as part of a truck, on truck trailers, and on railway flat cars.[1]

2. TECHNICAL REVIEW OF IPR REFRIGERANT OPTIONS

Industrial refrigeration equipment and process refrigeration equipment operate at any evaporator temperature from +100°F for heat pumps to -150°F for test chambers and some process manufacturing systems. Multiple refrigerant properties must be considered

[1] U.S. Environmental Protection Agency Protection of Stratospheric Ozone: Determination 35 for Significant New Alternatives Policy Program (October 31, 2019).

when choosing a refrigerant. When considering implementation of GWP restrictions on industrial process refrigeration equipment, consider the following chart.

	Refrigerant	Class	Flammability	Dew pt T (F)	Glide deg F
GWP 2200					
Allows	R410A	A1	non-flammable	-60	0.2
	R407C	A1	non-flammable	-34	7
	R407A	A1	non-flammable	-37	7
GWP 1500					
Allows	R448A	A1	non-flammable	-40	10
	R449A	A1	non-flammable	-37	10
	R134a	A1	non-flammable	-15	0
GWP 750					
Allows	R513A	A1	non-flammable	-18	0
	R450A	A1	non-flammable	-9	1.8
	R32	A2L	flammable	-61	0
GWP 150					
Allows	R454C	A2L	flammable	-36	14
	R455A	A2L	flammable	-61	23
	R717	B2L	flammable toxic	-28	0
	R290	A3	highly flammable	-44	0
	R744	A1	non-flammable	-70	0

Allowing refrigerants with GWP up to 2200 in the short term will allow buildings of low temperature systems with existing equipment using non-flammable refrigerants with low dew point temperatures (three gases with dew points below -34F). Dew point temperature is the temperature at which the refrigerant begins to boil at atmospheric pressure. Manufacturers avoid using refrigerant with an evaporating temperature below the dew point temperature at atmospheric pressure because a leak in the low-pressure side of the system could allow air ingress into the refrigerant. Air ingress brings with it the risk of refrigerant contamination or, in the case of flammable refrigerants, the possibility to make a flammable mixture inside the refrigeration system.

Therefore, industrial refrigeration systems with low evaporating temperatures require a dew point temperature below the lowest system temperature, whenever possible.

Most industrial refrigeration processes use flooded evaporators, where refrigerant boils in a pool of liquid in the evaporator, or the refrigerant is circulated with pumps from a storage vessel to the evaporator. These systems generally will not work using a refrigerant with a temperature glide higher than perhaps one-degree F.

The danger with high glide is that the refrigerant will separate into its constituents at different concentrations in different parts of the system, and a leak in any one area will change the remaining refrigerant blend. This will change its properties, boiling and condensing temperatures, and in the worst case, create a flammable mixture if the less flammable constituents of the blend are more concentrated in the area of a leak, potentially leaving the flammable constituents at a higher concentration in the system.

Whenever possible, industrial refrigeration systems are designed with low glide refrigerants. Note that even at 2200 GWP, two of the available choices have 7°F glide. These two, 407C and 407A, generally would not be applied in flooded evaporators. Only 410A meets all the requirements for low temperature, with the one added complexity that it requires higher design pressures, so retrofit in existing systems is not possible.

A 1500 GWP limit provides two refrigerant choices with suitable dew point temperatures, allowing low temperature systems to operate not in a vacuum. However, both have high glide (10°F) so flooded evaporators are not possible, requiring redesign of many process evaporators to direct expansion. The third refrigerant, R134a, has a high dew point temperature (-15°F) so it would be in a vacuum at low temperature, but at least the choices are non-flammable. These would require redesign of many process evaporators and retrofitting existing systems would not be possible. For new systems R134a could be used on the high stage of a CO_2 cascade system but would involve more complexity in the system design, multiple refrigerants in the same plant, and provisions in place for power outage to avoid overpressure of the CO_2 system.

A 750 GWP limit provides two non-flammable refrigerant choices, though both have dew point temperatures that are too high for low temperature systems, and one has 1.8°F glide. Systems could be designed above approximately -18°F evaporating temperature, but below that would be in a vacuum. The other refrigerants below 750 GWP is R32 and R454B, which are not allowed in building codes because they are flammable and may not be appropriate in some industrial process refrigeration settings regardless of building code changes. R32 has a low dew point temperature and no glide, so would be a good choice in new systems designed for the higher pressures, but not until flammable refrigerants are allowed. This would likely require the added cost of Class 1 Division 2 electrical controls in the machinery room where the equipment is housed, and probably glycol to circulate to the product areas, as circulation of a flammable refrigerant to process areas is also not currently allowed in the codes. Pressure levels with R32 are also higher than many current systems, which would require redesign of equipment. This is not a retrofit possibility. While it is a viable choice in the long term, the use of this as a refrigerant would require redesign of a great deal of equipment.

A 150 GWP limit leaves flammable and high glide refrigerant choices. These would require Class 1, Division 2 electrical controls in the machinery room where the equipment is housed. The extremely high glides (14°F and 23°F) would require redesign of all evaporators used in these systems to a direct expansion design that so far is quite new to low temperature systems, and yet to be proven effective. Retrofit would not be possible.

One possible system beneath the 150 GWP limit would be a cascade system with flammable refrigerants on the high stage, and perhaps CO_2 on the low temperature stage. R1233zd(e) was proposed as a non-flammable high stage refrigerant on a cascade system, but its dew point temperature at atmospheric pressure is 65°F. This is too high to be a practical or efficient intermediate temperature if CO_2 is used in the low stage.

Any time a cascade system is required, an additional heat transfer step is required, with a temperature difference in the heat exchanger that hurts efficiency. The efficiency penalty can easily be 15% on the overall system efficiency for the approach temperature in the cascade system heat exchanger. It is very easy to have a higher total equivalent warming impact (TEWI) CO_2 emission footprint due to the higher energy use required, offsetting any advantage of the possible direct emission of a higher GWP gas.

One other option below 150 GWP is the use of CO_2 transcritical systems. CO_2 is non-flammable and offers low GWP but also has characteristics that must be considered when applying such systems in order to optimize energy efficiency and serviceability. It does not condense above about 88°F, so the efficiency at high ambient temperatures may drop significantly, perhaps on the order of 30%. For this reason, designers must consider measures to ensure system efficiency such as the use of adiabatic gas coolers, as opposed to air cooled (dry) units. Such designs will significantly improve efficiency levels consistent with both traditional refrigeration systems and California's climate goals. In addition, the high pressures developed at standstill temperatures dictate very high pressure system designs. Some servicing methods are different and require training for electronic controls, charging, and start-up, although much of the fundamental refrigeration servicing skills convey. If low-GWP gases are being required in the name of reducing greenhouse gas emissions, also taking steps to ensure the overall energy efficiency of CO_2 transcritical systems will be critical going forward to avoid unnecessary energy use and associated emissions at power plants.

3. TRANSPORT REFRIGERATION

At the August 6th stakeholder meeting, CARB asked for feedback on possible transition timing and GWP capabilities for transport refrigeration units (TRUs). After discussing with members, AHRI strongly supports regulation in California aligned with the Canadian federal regulation, Canada's Regulation Amending the Ozone-depleting Substances and Halocarbon Alternatives Regulation, which can be accessed here: http://www.gazette.gc.ca/rp-pr/p2/2017/2017-10-18/html/sor-dors216-eng.html. The regulation specifies that commercial or industrial mobile refrigeration systems must comply with a GWP limit of 2200 by January 1, 2025. This proposal is included in the AHRI proposal table in the next section. The consistency between Canada and the U.S. is important because TRUs currently use R404A in these regions. TRUs have already transitioned to R452A (GWP < 2200) in the EU. The U.S. has already approved R452A for use in new and existing TRUs. Consistency is important to ensure consumer costs are minimized.

4. GWP AND TIMING PROPOSAL TABLE

The great majority of large process refrigeration systems use hydrocarbons as refrigerant if they are used in hydrocarbon processing plants where trained personnel and appropriate safety measures are in place. This will not change.

The great majority of large food freezing and cold storage facilities use ammonia (R717) refrigerant today, or ammonia with CO_2 cascade. Per International Institute of Ammonia Refrigeration (IIAR) guidelines, ammonia systems do not need to have classified electrical equipment if equipped with the appropriate controls and ventilation. These facilities also have trained personnel and PSM/RMP programs in place to assure safety. This also will not change.

However, there are facilities in heavily populated or heavily regulated areas where ammonia and/or hydrocarbons may not be allowed or are too costly to use, making up perhaps 5 - 10% of the IPR market. Alternative refrigerants are necessary for these applications to allow low temperature freezing or chilling. The proposed low GWP requirements in the table below will account for this limited percentage of IPR applications. The proposals in the table apply only to new equipment, not for existing or retrofit equipment.

	AHRI Proposal for New Equipment		
Equipment Type	**Charge**	**GWP**	**Date**
Refrigerated Transport units	<50 lbs	2200	Jan 1, 2025
AC/Comfort Cooling Chillers	>50 lbs	750	Jan 1, 2024
Refrigeration Chillers in ice rinks		750	Jan 1, 2024
Refrigeration Chillers operating above -10 F		1500	Jan 1, 2024
Refrigeration Chillers operating between -10 to -50 F		2200	Jan 1, 2024
IPR equipment operating above -50 F		2200	Jan 1, 2024
IPR equipment operating below -50 F		exempt	
Medical, scientific or research equipment		exempt	

5. EXEMPTIONS

In its September 20, 2019 comments, AHRI asked that CARB consider including a clause within their regulation to account for necessary exceptions similar to Canada's essential purpose permit option in their Ozone-depleting Substances and Halocarbons Alternatives Regulations (ODSHAR). This is especially critical to equipment installed in areas where ammonia would never be approved by an Authority Having Jurisdiction (AHJ) such as cold storage and industrial refrigeration applications. During the transition to low-GWP alternatives with such complex systems the exemption process will allow for essential equipment or applications to safely and efficiently phase down the use of high GWP refrigerants on a permit basis.

AHRI greatly appreciates the opportunity to provide these comments. We look forward to further engagement with CARB to provide any additional information or clarification of the above proposals. Should you have any questions regarding this submission, please contact Helen Walter-Terrinoni [hwalter-terrinoni@ahrinet.org, (302) 598-4608] or Jennifer Kane [jkane@ahrinet.org, (703) 600-0304].

Respectfully,

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Cc: Helen Walter-Terrinoni