Shaping Tomorrow's Built Environment Today

MINUTES

Refrigeration Committee (REF)
January 29, 2017
Caesars Palace
Las Vegas, NV

MEMBERS PRESENT:
Karim Amrane, *Chair*
Nick Shockley, *Vice-Chair*
Roberto Aguilo
Didier Coulomb
Martin Dieryckx
Charles Hon
Glenn Hourahan, *Consultant*
Barbara Minor
Shamila Nair-Bedouelle
Rajan Rajendran
Jason Robbins
Richard Royal
Dave Rule
William Walter, *BOD Ex-O*

MEMBERS NOT PRESENT:
Pat Graef, *Coordinating Officer*

ASHRAE STAFF:
Steve Hammerling, AMORTS

GUESTS:
Trevor Bellon
Ray Cole
Ken Cooper
Brian Fricke
Stephen Gill
Rainer Jakobs
Dustin Lilya
Greg May
Andy Pearson
Michael Petersen
Ivan Rydkin
Vishal Sharma
Arvind Surange
Jim Wolfe
Shitong Zha

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MOTIONS

No.	Motion	Status
1	the minutes from the REF Fall Meeting be approved	PASSED
2	REF recommends that DRSC recommends that Technology Council recommends that the BOD approve the revision to the *Ammonia as a Refrigerant* PD.	PASSED
3	REF recommends that DRSC recommends that Technology Council reaffirm the *Refrigerants and their Responsible Use* PD.	PASSED
4	DRSC recommends that Technology Council recommends that the Board of Directors (BOD) ExCom initiate a revision of the *Refrigerants and their Responsible Use* position document (PD).	PASSED

ACTION ITEMS – Winter 2017

No.	Responsibility	Action Item	Page
1	Staff	Promote awards as has typically been done in Insights, Members First, contacting non-winning submissions, etc.	2
2	REF	Help identify projects that may be submitted for REF awards	2
3	Rajendran, Minor, Nair-Boudelle	Start to develop draft revisions to *Refrigerants and their Responsible Use* PD	4
4	REF	Suggest DL speakers on new refrigerants to Hon/CTTC	5
5	Staff	Seek outcome of activities listed in strategic plan	6
6	Hon, Rajendran, Minor, Walters	Discuss how REF can be promoted as a technical resource and how process would work	6
7	Shockley, Aguilo, Martin and Royal	Explore and develop a plan for how REF can outreach and participate with international refrigeration events and conferences.	6
8	Royal and Robbins	Attend Associate Society Alliance meeting in Las Vegas and report to REF in spring.	6
9	Amrane	Develop a presentation from REF to outside groups such as USNC IIR and ASHRAE Associate Society Alliance organizations on how REF can liaise and interact with these sorts of groups	6

ACTION ITEMS – Fall 2016

No.	Responsibility	Action Item	Status
FA-1	Staff	Send Hon information on when the CTTC meets at ASHRAE meetings	Complete

FA-2	Staff	Staff to request Rule provide summary of how REF comments on Ammonia PD were addressed/resolved	Complete
FA-3	Staff	Send all review comments on Ammonia PD to REF	Complete
FA-4	REF	REF members were asked to volunteer for Developing Economies subcommittee chair if interested	Complete
FA-5	Staff	Contact ASHRAE Staff working on UNEP involvement to assure REF is represented on the UNEP/ASHRAE partnership committee	Complete
FA-6	Amrane	Amrane to email responsible parties for MBOs to prepare for Las Vegas Meeting	Complete
FA-7	Amrane	Amrane to discuss REF more involvement on regulatory matters impacting refrigeration with Walter and take to Tech Council as appropriate	Ongoing
FA-8	Staff	Send the Refrigerants and their Responsible Use PD to REF for review to recommend retirement revision or reaffirmation	Complete

ACTION ITEMS – Spring 2016

No.	Responsibility	Action Item	Status
SP-2	Amrane, Diercyzk	Summarize energy efficiency HVAC&R programs/standards in Europe, Middle East, Australia, Japan, India and elsewhere in the world for a presentation in St. Louis.	Ongoing

LIST OF ATTACHMENTS

No.	Attachment
A	BOD Ex-O Presentation
B	Ammonia as a Refrigerant PD revision
C	Refrigerants and their Responsible Use PD
D	CTTC report
E	Regulatory Issue Update
F	MBOs 2016-2017 update
G	MBO #2 update

LIST OF ACRONYMS

AC	Air Conditioning	HFO	Hydrofluoro olefin
ACCA	Air Conditioning Contractors of America	HVAC&R	Heating, Ventilating, Air Conditioning & Refrigeration
AHRI	Air-conditioning, Heating & Refrigeration Institute	IIAR	International Institute of Ammonia Refrigeration
AHRTI	Air-conditioning, Heating & Refrigeration Technology Institute	IIR	International Institute of Refrigeration
AI	Action Item	MBO	Management by Objectives
ALI	ASHRAE Learning Institute	MOP	Manual of Procedures
AMORTS	Assistant Manager Research & Technical Services	NATE	North American Technician Excellence
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers	PD	Position Document
BOD	Board of Directors	PDH	Professional Development Hour
CNV	Chair Not Voting	PMS	Project Monitoring Subcommittee
CO_2	Carbon Dioxide	REF	Refrigeration Committee
CTTC	Chapter Technology Transfer Committee	ROB	Rules of the Board
DL	Distinguished Lecturer	RP	Research Project
DOE	Department of Energy	SSPC	Standing Standard Project Committee
DRSC	Document Review Subcommittee	STBE	Science & Technology for the Built Environment
Ex-O	Ex-Officio	TC	Technical Committee
GCCA	Global Cold Chain Alliance	TRP	Tentative Research Project
GRMI	Global Refrigerant Management Initiative	UNEP	United Nations Environment Programme
GWP	Global Warming Potential	USNC	United States National Committee (for the IIR)
HFC	Hydrofluorocarbons		

1. CALL TO ORDER

Chair Karim Amrane called the meeting to order at 8:00 AM. Members and guests introduced themselves.

2. REVIEW OF AGENDA

Amrane confirmed quorum was met. No changes were suggested to the agenda.

3. MINUTES

A. It was moved (RR) and seconded (NS) that,

(1) the minutes from the REF Fall Meeting in be approved.

MOTION 1 PASSED: 11-0-0, CNV

BACKGROUND: Minutes were distributed in October 26th email.

4. CHAIR'S REPORT – Amrane

A. Motions from Past Meetings Requiring Higher Body Approval
No motions from Annual required higher approval.

B. New Information Items for REF

1. *2L Research*
Amrane reported the 2L research is ongoing. There are 3 AHRTI projects moving forward now. One is expected to be completed by the end of February and two more expected to be done by end of April 2017. Amrane noted the DOE is conducting a project as well related to evaluating and optimizing refrigerant charge in various systems.

There are three ASHRAE projects as well:

- *1806-RP, Flammable Refrigerants Post-Ignition Simulation and Risk Assessment Update* – Project is underway. It is expected to be completed in 12 months.
- *1807-TRP, Guidelines for Flammable Refrigerant Handling, Transporting, Storing and Equipment Servicing and Installation.* - A bidder was approved in Las Vegas for Completion is expected in the fall.
- *1808-TRP, Servicing and Installing Equipment using Flammable Refrigerants: Assessment of Field-made Mechanical Join* - Project is currently out for bid. Bidding closes February 20th.

2. *GRMI updates*
REF continues to monitor Global Refrigerant Management Initiative (GRMI) activities. The focus of the GRMI is on education, training, certification of technicians to reduce refrigerant emissions. The GRMI steering committee includes ASHRAE with Walid Chakroun as the ASHRAE representative. The GRMI is meeting in Las Vegas to set up 2017 work plan. A website is planned.

5. VICE-CHAIR'S REPORT – Shockley

A. Fiscal Report
Shockley noted there are no changes to request to REF budget at this time.

B. MOP/ROB/Reference Manual
No changes for this meeting to these documents.

6. BOD/TECH COUNCIL REPORTS

A. BOD EX-Officio – Walter

Walter presented an Ex-O report to committees (**Attachment A**). Highlights include:

- Las Vegas meeting had record attendance and show floor space.
- Members are asked to nominate committee members at www.ashrae.org/nominate
- New international mailing for ASHRAE Journal
- Free member access to Science & Technology for the Built Environment (STBE) - www.ashrae.org/stbe.
- Four conferences outside of North America planned for 2017
- Seeking ideas on how ASHRAE can help refrigeration industry

Walter thanked all for time and service to ASHRAE activities and asked for any feedback from committee members to take to the BOD. Graef was not in attendance.

7. AWARDS

A. *Milt Garland & Comfort Cooling Awards*

1. Presentations in Las Vegas at Awards plenary

Claude Dumas was honored at the Plenary Session as winner of the Milton W. Garland Refrigeration Award. Andy Pearson was honored with the Comfort Cooling Award.

2. Award nominations

Nominations for the next set of Awards is May 1st. Staff will promote awards as has typically been done in Insights, Members First, contacting non-winning submissions, etc. (**AI #1**). Members are encouraged also to identify projects that may be submitted. A judging subcommittee can be formed in the spring (**AI #2**).

B. *Briley Award Presentation*

1. Kenneth Elovitz - Rooftop Refrigeration Unit Performance

The 9th annual George C. Briley Award for the best refrigeration-related article published in the ASHRAE Journal was awarded to Mr. Kenneth Elovitz, for his article "*Rooftop Refrigeration Unit Performance".* Mr. Elovitz could not attend so his plaque would be mailed. Articles for the next Briley Award will be reviewed in the fall.

8. SUBCOMMITTEE REPORTS

A. ASHRAE Learning Institute (ALI) – **Royal**

Royal noted there are four hours of course content currently outlined. A subcommittee is meeting early March to review content. Royal will be meeting with ALI manager Karen Murray to review structure and to align with ALI format. REF could eventually consider programs to announce the course. The intent is to eventually provide PDHs.

Royal agreed that REF could eventually link courses to UNEP by making available to chapters. ACCA and outside groups may also be interested in the course or derivative products. Royal agreed to update REF on progress at the REF spring meeting.

B. Programs – **Dieryckx**

1. Las Vegas

Dierycxk noted the following were approved and would take place at the Winter Meeting in Las Vegas:

- Workshop 2 - Optimization of Direct AC Systems with Low GWP Refrigerants (Dierycxk)
- Workshop *6* - Food Cold Chain for Developing Countries (Coulomb)
- Seminar 64 -(co-sponsor) Research Update on Activities Toward the Safe Use of Low GWP Flammable Refrigerants

- *Seminar 72 - Introducing the Guide for Sustainable Refrigerated Facilities and Refrigeration Systems (1634 –RP)*

2. Long Beach

The following programs were discussed for Long Beach. Dierycxk agreed to submit before Feb. 6th deadline:

- Safety Considerations for AC and Refrigeration Equipment in Developing Economies – Seminar
- Draft proposal on program to consider in Las Vegas for a program in Long Beach on CO_2 Installation Do's and Don'ts

Corey Metzger from CEC visited REF. Noted will have REF track at winter meeting next year. Offered to help with producing reviews, etc. Vikrant Aute is the Track 3, Refrigeration chair and could be emailed for input to help get through he submission process.

C. Refrigeration Handbook chapters – **Shockley**
Shockley reached out to Fenton ahead of the meeting but did not connect. Cesar Lim is helping with reviews as well. Chapter R42 needs most immediate attention for a reviewer.

D. Position Documents (PD)

1. *Ammonia as a Refrigerant Position Document* – **Rule**
Rule summarized that the PD committee approved the latest draft unanimously. The PD committee reviewed and considered all comments and made changes based on input. Generally, the PD was revised to broaden and address international standards and codes, updated references, and tables on health and safety. Rule suggested putting the PD ahead at this time for consider approval and publication of the revised PD.

There was a suggestion for a formal ASHRAE tool or method to collect comments for PDs to consider in the next rewrite. This may be an idea for innovative idea list.

Members asked generally if there was a reason for taking a specific positon on ammonia but no other specific refrigerants. This may imply a controversy or more importance here. Rule noted there was valuable information in this PD that may or may not be available in other ASHRAE publications. REF discussed and concluded that long term, the goal could be for the *Ammonia as a Refrigerant* PD content to be merged or coalesced with a future revision (2020) of the *Refrigerants and their Responsible Use* PD.

It was moved (DR) and seconded (RA) that,

(2) REF recommends that DRSC recommends that Technology Council recommends that the BOD approve the revision to the *Ammonia as a Refrigerant* PD.

BACKGROUND: The revised PD is shown in **Attachment B.** The stated purpose of the revision was to assure compliance with the latest PD template, to assure consistency with *Refrigerants and their Responsible Use* PD, to include recent technical advancements, and to update references. The current *Ammonia as a Refrigerant* PD is set to expire July 2, 2017. The PD committee approved the revision unanimously (7-0-0 CV). REF is the cognizant technical committee, participated in the review, offered comments to the PD committee and recommends approval.

MOTION 2 PASSED: 9-0-1 CNV

2. *Refrigerants and their Responsible Use* PD

Amrane asked for recommended decisions on this PD considering it expires later this year. Walter noted he chaired initial version and that much has happened since with updates to the Montreal Protocol, A2L refrigerants and other refrigerant developments. REF concluded changes should be made to include latest Montreal Protocol amendments, and updates on HFC and HFO use and regulations. REF thought an expedited revision and reaffirmation of the current PD to avoid the information from becoming unavailable during an expedited revision.

As noted earlier, REF discussed the need for the two ASHRAE PD's on refrigerants to eventually coalesce into a single PD covering all refrigerants. Information from the *Ammonia as a Refrigerant* PD would be included in the *Refrigerants and their Responsible Use* PD.

Nair-Bedoulle urged that UNEP is seeking updated guidance from ASHRAE. Amrane asked a subcommittee (Minor, Rajendran, Nair-Boudelle) to start to develop draft revisions to *Refrigerants and their Responsible Use* to address changes discussed here (**AI #3**).

It was moved (RR) and seconded (BM) that,

(3) REF recommends that DRSC recommends that Technology Council reaffirm the *Refrigerants and their Responsible Use* PD.

BACKGROUND: The current PD (**Attachment C**) expires July 2, 2017. A separate motion requests a revision of the PD. This reaffirmation would prevent expiration of the PD until the work of the revision committee can be completed. The intent is for the revised PD to replace this reaffirmed version as soon as possible.

MOTION 3 PASSED: 12-0-0 CNV

It was moved (RR) and seconded (NS) REF recommends that,

(4) DRSC recommends that Technology Council recommends that the Board of Directors (BOD) ExCom initiate a revision of the *Refrigerants and their Responsible Use* position document (PD).

BACKGROUND: The intent for the revision would be to update the PD to reflect advancements since the initial publication and specifically changes from the Kigali Amendment to the Montreal Protocol. UNEP has expressed that updated guidance from ASHRAE is sought as soon as possible.

MOTION 4 PASSED: 12-0-0 CNV

E. Developing Economies – **Amrane**

Coulomb agreed to chair REF's Developing Economies subcommittee.

F. UNEP/ASHRAE Partnership – **Nair-Bedouelle**

Nair-Bedoulle presented a few slides highlighting UNEP/ASHRAE partnership activities. She noted that an MOU was signed three years ago and a work plan for 2017-2018 is being worked out. Main goal of the work plan will be to work beyond high GWP refrigerants. Also, there is a Refrigerant Driving License steering committee working to develop a program.
UNEP is co-organizing a conference on sustainable management of refrigerants in marine sector. It was noted lecturers are sought from ASHRAE. UNEP may also be seeking generation

or review of fact sheets and documents for various conferences and topics. Nair-Bedoulle requested all consider supporting these efforts as well as other workshops at the regional and sub regional level.

9. OTHER REPORTS

A. Chapter Technology Transfer Committee (CTTC) Liaison Report (Hon)
Hon attended CTTC meetings in Las Vegas and gave a report to CTTC (**Attachment D**). He noted CTTC is strongly seeking speakers who know new alternate refrigerants to be added to Distinguished Lecturer (DL) list and asked REF members to suggest DL speakers on new refrigerants to CTTC (**AI #4**).

B. Consultant Report
Royal met with the chair of the project monitoring subcommittee (PMS). Chapters were reviewed and commented on. PMS is meeting tomorrow. RP-1634, *Guide for Sustainable Refrigerated Facilities and Refrigeration Systems*, is progressing with the publication anticipated later this year.

C. Refrigerant Issue Update – **Amrane**
Amrane presented report on Refrigerant Issues at the meeting (**Attachment E**).

D. Liaisons

1. *TCs & SSPCs*
REF will continue to liaison with relevant ASHRAE TCs and SSPCs. Please continue to attend meetings and report as appropriate.

   Hon reported SSPC 72 is voting on a revision either here at the Winter Meeting or next meeting. Goals include addressing differences in DOE standard and standard 72 and addressing a lack of method of test for CO_2 systems.

   Hon noted also that SSPC 210 on walk in cooler method of test was formed and is meeting in Las Vegas.

2. *IIR* - **Coulomb**
Coulomb reported IIR's support of the ASHRAE Fisheries conference. IIR is also working on a dictionary of HVAC&R terms (International Dictionary of Refrigeration) with an eventual goal of aligning with ASHRAE and other industry resources.

3. *UNEP* - **Nair-Bedouelle**
REF remains supportive of the Work Plan of ASHRAE-UNEP Global Cooperation Agreement and the Developing Economies Ad Hoc Final Report. REF has MBOs focused on the implementation of these goals.

4. *IIAR* – **Rule**
Rule noted the IIAR Annual Conference is early this year Feb. 26 – Mar. 1 in San Antonio. IIAR is working on a number of standard actions including a standard on industry definitions, addenda to Standard 2, a major revision to Standard 6, and a standard on CO2. IIAR is also starting work on establishing an education academy.

5. *GCCA* liaison report
Vallort submitted formal GCCA liaison report. This was sent to REF (and relevant TC's) in Nov 20^{th} email.

6. *NATE* liaison report
   Report sent to REF in Nov 16th email

10. STRATEGIC ISSUES

A. MBO Updates – MBO leaders
   Amrane reviewed MBOs for the current Society Year. Updates will be reported to Tech Council (**Attachment F**).

   MBO #2 - *Support of ASHRAE Developing Economy Objectives*
   Subcommittee members developed a presentation (**Attachment G**). Highlights included a focus on ASHRAE technical programs for Las Vegas, programs from AHRI/UNEP/DOE in Las Vegas, a workshop on Sustainable Technologies for Stationary Air Conditioning Workshop, and a path forward. ASHRAE staff was asked to seek outcome of activities listed in strategic plan (**AI #5**).

   MBO #3 - *UNEP Implementation of UNEP Partnership Goals*
   Amrane noted REF should participate and know what role should be played in advancing these goals. Nair-Bedoulle summarized recent developments earlier in the meeting. Noted 1634-RP is a result of this relationship. REF can perhaps help in distribution of this publication when available later this year.

   MBO #4 - *Serve as the Technical Experts for Refrigeration related issues for ASHRAE*
   REF wishes to formalize a process to help REF be this resource. Currently, the issue is that REF is not receiving such technical requests. A subcommittee (Hon, Rajendran, Minor, Walters) agreed to discuss how this can work, how REF can be promoted as a technical resource (**AI #6**).

   MBO #5 - *Efficient communication and operation of the REF Committee*
   This MBO can be kept for consideration of future chair. MBO can be changed to effective vs. efficient.

   Amrane asked REF members to think about suggestions to next year's MBOs to be sent to Shockley.

B. Tech Council Innovative Ideas
   1. *International REF Meeting*
      REF discussed proposal for REF to hold meetings in conjunction with international refrigeration events such as conferences, workshops, Montreal Protocol, etc. An alternative to the previously proposed solution could be REF outreach and participation on behalf of ASHRAE at these interactions refrigeration events and conferences to explore further how REF can meet this goal. Shockley, Aguilo, Martin and Royal were asked to explore further and develop a plan (**AI #7**).

      REF will also liaise with ASHRAE Associate Society Alliance to explore opportunities. Royal and Robbins agreed to attend Associate Society Alliance meeting in Las Vegas (**AI #8**) and can report to REF in spring. REF could also work with USNC-IIR. REF may wish to develop a presentation for liaising or presenting to these sorts of groups (**AI #9**).

   2. *New Suggestions*
      The idea for a tool for tracking position document comments while published for next revision could be innovative idea. No others ideas for list were suggested.

C. REF Strategic Planning

1. *Themes for next Society Year*
   - codes/standards issues
   - refrigerant transition to 2L
   - focus on developing economies
   - energy efficiency
2. *International Participation*
   - ASHRAE's involvement in international discussions?
   - ASHRAE involvement in outside organizations?
   - International members participation in ASHRAE

11. NEXT MEETING

REF may hold a spring web meeting. REF will next meet face to face at the ASHRAE Annual Meeting in Long Beach, CA on Sunday, June25, 2017 from 8a-12pm.

12. ADJOURNMENT

Committee adjourned at 12 PM.

ASHRAE UPDATE

ExO Report to Committees
2017 Winter Conference

ASHRAE

AHR EXPO/ASHRAE CONFERENCE

- AHR Expo
  - Record breaking exhibit space anticipated
  - More than 2,000 exhibitors and 60,000 industry professionals
  - Attendees from every state in the U.S. and 150 countries worldwide
- ASHRAE Conference
  - 2,761 attendees
  - 699 committee meetings
  - 248 presentations via 331 speakers in Technical Program



ASHRAE WANTS YOU!

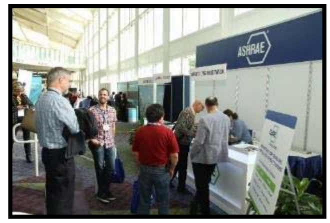
- Standing committee appointments sought for 2017-18
- Join President-Elect Bjarne Olesen as he works to “Extend Our Community,” through the global community, technical horizons and value to members
- www.ashrae.org/nominate
- Nominations due by Feb. 17

PRESIDENTIAL INITIATIVES – PRESIDENT’S LUNCHEON PREVIEW

- Internship Program – launched
- Chapter Opportunity Fund – funds being distributed to regions and chapters for implementation
- App Portfolio – expansion underway
- More details shared at President’s Luncheon on Monday. Don’t miss out!

NEW EDUCATIONAL COURSES

- Cogeneration from the Basics through Operation
- Complying with Standard 90.1-2016
- Complying with the Requirements of Standard 62.1-2016
- New ASHRAE-Classified Refrigerants to Meet Society's Changing Needs
- Complying with Standard 90.1-2016 Appendix G
- Variable Refrigerant Flow System Design & Applications
- Design of Affordable and Efficient Ground Source Heat Pump Systems



NEW INTERNATIONAL MAILING

- New international mailing service to ensure faster and more accurate delivery of ASHRAE Journal
- Began with December 2016 issue

FREE ACCESS TO STBE

- ASHRAE members now have **free** online access to *Science and Technology for the Built Environment*
- Provides comprehensive reporting of original research in science and technology related to the stationary and mobile built environment
- Available using ASHRAE member login at www.ashrae.org/stbe

RECENT PUBLICATIONS AND STANDARDS

- Standard 15-2016, *Safety Standard for Refrigeration Systems*
- Standard 34-2016, *Designation and Safety Classification of Refrigerants*
- Standard 90.1-2016, *Energy Efficiency Standard for Buildings Except Low-Rise Residential Buildings*
- Standard 90.4-2016, *Energy Standard for Data Centers*
- User's Manuals for Standards 55 (thermal comfort), 62.1 (ventilation) and 62.2 (residential ventilation)
- Duct Size Calculator

UPCOMING PUBLICATIONS

- *ASHRAE Design Guide for Cleanrooms* (slated for April publication)
- *ASHRAE Design Guide for Duct Systems* (to be approved in Las Vegas)
- *ASHRAE Design Guide for Dedicated Outdoor Air Systems* (slated for June publication)
- *ASHRAE Design Guide for Air Terminal Units* (possible approval in Las Vegas)
- *Advanced Energy Design Guide for K-12 Schools: Achieving Zero Energy*

ASHRAE CONFERENCES

- **Second International Conference on Energy and Indoor Environment for Hot Climates,** Doha, Qatar, Feb. 26-27
- **Delivering Resilient High-Performance Buildings,** Loughborough, UK, April 5-6 (in collaboration with CIBSE)
- **Sustainable Management of Refrigeration Technologies in Marine and Off-Shore Fisheries Sectors,** Bangkok, Thailand, April 6-8
- **ASHRAE Webcast,** Take Control: Using Analytics to Drive Building Performance, April 20
- **2017 ASHRAE Annual Conference**, Long Beach, Calif., June 24-28
- **ASHRAE 2017 Building Performance Analysis Conference,** Atlanta, Ga., Sept. 27-29
- **Second Developing Economies Conference**, Delhi, India, Nov. 10-11

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www.ashrae.org

ASHRAE Position Document on

Ammonia as a Refrigerant

Approved by ASHRAE Board of Directors
February 1, 2017

Expires
February 1, 2020

COMMITTEE ROSTER

The ASHRAE Position Document on "Ammonia as a Refrigerant" was developed by the Society's Refrigeration Committee. Position Document Committee formed on January 8, 2016 with Dave Rule as its chair.

Dave Rule, Chair
IIAR
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Caleb Nelson
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Missoula, MT, USA

Cognizant Committees

The chairperson of Refrigerant Committee also served as ex-officio members:

Karim Amrane
REF Committee
AHRI
Bethesda, MD, USA

HISTORY

of

REVISION / REAFFIRMATION / WITHDRAWAL DATES

The following summarizes the revision, reaffirmation or withdrawal dates:

1/28/1993 – Board of Directors approves Position Document titled *Ammonia as a Refrigerant*

1/17/2002 – Board of Directors approves revised Position Document titled *Ammonia as a Refrigerant*

1/26/2006 – Board of Directors approves reaffirmation of Position Document titled *Ammonia as a Refrigerant*

1/30/2010 – Technology Council approves reaffirmation of Position Document titled *Ammonia as a Refrigerant*

6/30/2013 – Technology Council approves reaffirmation of Position Document titled *Ammonia as a Refrigerant*

7/2/2014 – Board of Directors approves revised Position Document titled *Ammonia as a Refrigerant*

2/1/2017 – Board of Directors approves revised Position Document titled *Ammonia as a Refrigerant*

Note: Technology Council and the cognizant committee recommend revision, reaffirmation or withdrawal every 30 months.

CONTENTS

ASHRAE Position Document on

"Ammonia as a Refrigerant"

SECTION **PAGE**

ABSTRACT

Ammonia has been continuously used as a refrigerant since the initial practical use of the vapor-compression refrigeration cycle was developed. It has remained the main refrigerant used in industrial refrigeration systems because of its superior thermodynamic properties and low cost. Regulatory oversight on refrigerants such as CFC, HCFC, and other synthetic refrigerants, have re-focused attention on ammonia to emerge as one of the widely used refrigerants that, when released to the atmosphere, does not contribute to ozone depletion and global warming. Ammonia is generally considered to be benign to the environment. ASHRAE encourages the continued use of ammonia for - industrial and commercial refrigeration, food preservation, indirect space conditioning, heat pumps and other applications. ASHRAE participates in a variety of programs such as a dedicated chapter in the Refrigeration Handbook and several current and former research projects to promote the economic and environmental benefits of ammonia refrigeration and will continue to provide guidance for the proper design, safe use and management of risk.

EXECUTIVE SUMMARY

Globally, there is a growing interest in ammonia as a refrigerant, both by itself, and in cascade refrigeration systems with carbon dioxide and other secondary system designs. Regulatory oversight on CFC, HCFC, and other synthetic refrigerants, have re-focused attention on ammonia to emerge as one of the widely used refrigerants that, when released to the atmosphere, does not contribute to ozone depletion and global warming. New technology and equipment is leading to low and reduced ammonia charge designs. The application of these new low charge systems and packages creates an opportunity to use ammonia systems in a broad range of industrial, commercial and indirect space conditioning applications that would not have been considered with traditional designs. These changes will require industry to provide proper recommendations for both design safety and guidance for regulatory and code agencies.

Ammonia is an efficient and popular refrigerant due to its superior thermodynamic properties and low cost. Ammonia is environmentally benign, having zero GWP and zero ODP. It is hazardous when released in large quantities due to its toxicity. However, ammonia does exhibit a unique refrigerant characteristic due to its irritating odor. Persons exposed to an ammonia release will not voluntarily stay near concentrations that are health-threatening. Although ammonia will burn in a narrow range of high concentrations, it is difficult to ignite and will not support combustion after the ignition source is withdrawn. Ammonia has an ASHRAE flammability class of 2L, low flammability.

ASHRAE encourages the continued use of ammonia for industrial and commercial refrigeration, food preservation, indirect space conditioning, heat pumps and other applications. ASHRAE participates in a variety of programs to promote the economic and environmental benefits of ammonia refrigeration and will continue to provide guidance for the proper design, safe use and management of risk.

1. THE ISSUE

Refrigerant selection has become increasingly complex in recent years. Globally, the interest in ammonia and other natural refrigerants has become more focused due to increased regulatory oversite on the use of CFC, HCFC, and other synthetic refrigerants. The consideration of these refrigerants continues to come under question due to the environmental concerns caused from ozone depleting potential (ODP), global warming potential (GWP), energy efficiency, total equivalent warming impact (TEWI) and life cycle climate performance (LCCP).

Ammonia is a natural refrigerant that has been used for many years in a variety of applications due to its high thermal efficiency. Since ammonia is environmentally benign, having zero (GWP) and zero (ODP) characteristics, ammonia is emerging as one of the primary natural refrigerants of choice.
New technology is leading to low and reduced ammonia charge designs. The application of these new low charge systems and packages creates an opportunity to use ammonia in a broad range of new industrial, commercial and indirect space conditioning applications that would not have been considered with traditional designs. These changes will require industry to provide proper recommendations for both design safety and guidance for regulatory and code agencies.

2. BACKGROUND

Ammonia (chemical symbol NH3, United Nations Chemical I.D. #1005) is produced both naturally and as a byproduct of numerous man-made reactive processes. Large amounts of naturally occurring ammonia gas come from livestock animals, soil surfaces and even the human body. Manmade processes that emit ammonia to the atmosphere include fuel combustion processes and sewage treatment plants.

The nitrogen component of ammonia was first recognized as an important fertilizer around 1840, and ammonia was first used as a refrigerant around 1850. Ammonia was first commercially produced in the United States about 1880 as a distillation by-product of coal processing to produce coke and coal gas.

The first direct-synthesis commercial process was developed in Germany by Fritz Haber and Carl Bosch in 1913. The wide variety of ammonia uses throughout agriculture and industry, combined with varied and highly efficient manufacturing processes, has kept the costs of commercially manufacturing ammonia low. Natural gas is one of the feedstocks used for large scale ammonia production. The rapid increase in the availability of natural gas in the U.S. and elsewhere due to new drilling technologies has kept the cost of this feedstock down, helping to keep down the cost of the ammonia product.

2.1 Ammonia Specification and Applications

Ammonia is an alkaline, colorless chemical compound that is well recognized as the basis for household cleaning products. It also has many agricultural, industrial and commercial uses. It is available in five generally recognized grades—fertilizer, refrigerant, federal, metallurgical, and semiconductor—depending on its level of purity.

Refrigeration grade ammonia is 99.98 percent pure and is relatively free of water and other impurities (maximum: 150 ppm water, 3 ppm oil, 0.2 ml/g non-condensibles). It is readily available, inexpensive, operates at pressures comparable with other refrigerants and is capable of absorbing large amounts of heat when it evaporates.

Of the estimated 140 million metric tons of ammonia produced commercially throughout the world in 2013 (8.7 million metric tons in the United States), over 80 percent is used for agricultural purposes[1]. Some of the agricultural uses of commercial ammonia include:

- Direct injection into soil as a fertilizer.
- Production of urea (colorless crystalline material that is a highly concentrated form of nitrogen fertilizer and a source of protein in livestock feeds).
- Pre-harvest cotton defoliant.
- Anti-fungal agent on certain fruits.
  The remaining 20 percent of commercially manufactured ammonia is used for numerous industrial applications, such as:
- Direct injection in selective catalytic reduction control of nitrogen oxides for stack emissions.
- Direct injection of ammonium hydroxide for stack emissions to neutralize sulfur oxides from sulfur-containing fuels.
- Nitrogen component for the manufacture of explosives such as TNT and nitroglycerin.
- Closed-loop refrigerant in many industrial and indirect commercial refrigeration systems.
- Neutralizing agent for acid constituents in sewage treatment plants.
  Less than 2 percent of all the ammonia commercially produced in the world is used as a refrigerant.

2.2 Refrigeration Uses of Ammonia

With continued regulatory oversight on the use of synthetic or halocarbon refrigerants, alternative refrigerants for use in existing refrigeration systems are actively being investigated.

Ammonia is one alternative refrigerant for new, replacement, and existing refrigeration system designs, where compatible. Ammonia has a low boiling point (-28°F @ 0 psig), an ozone depletion potential (ODP) of 0.00 when released to atmosphere and a high latent heat of vaporization eight (8.17 at -28°F) times higher than R-12 and six (6.18 at -28°F) times higher than R- 134(a). In addition, ammonia in the atmosphere does not directly contribute to global warming. These characteristics result in a highly energy-efficient vapor-compression cycle with ammonia as the refrigerant with minimal environmental impact.

Ammonia's use in the HVAC&R industry will increase as regulatory and code officials become informed of its relative safety. Applications for ammonia-based refrigeration systems include thermal storage systems, HVAC chillers, process cooling, air conditioning, winter sports, district cooling systems, heat pump systems, supermarkets, convenience stores, and increasing output efficiencies for power generation facilities. Ammonia is also already being used in large heat pump installations and supermarkets, as well as in several high-profile projects, including the International Space Station and Biosphere II.

Ammonia is increasingly used in cascade refrigeration systems with carbon dioxide. In these systems, ammonia is used in the high-temperature stage to reject heat to the environment. Carbon dioxide is used in the low-temperature stage to absorb heat from the load to be cooled, and to reject the heat to the ammonia high-temperature stage. Such systems allow the use of ammonia in a wider range of applications, because the less hazardous carbon dioxide can be used in more locations, while the highly efficient ammonia can be kept in a central mechanical room or rooftop package. Ammonia is also used in conjunction with other secondary fluids, such as water or glycol, for the same reasons noted above.

2.3 Health and Safety

The National Institute for Occupational Safety and Health (NIOSH), in its 2007 Pocket Guide[2], has set the Immediate Danger to Life or Health (IDLH) level, the level at which an individual could be exposed for 30 minutes without a respirator and not experience any lasting health effects, at 300 parts per million. The purpose of IDLH is to establish when the maximum level of respiratory protection is required by OSHA regulations. Ammonia's sharp, irritating, pungent odor actually helps reduce exposure to potentially dangerous concentrations. The average odor threshold is 5 ppm[3], well below concentrations that may cause harmful effects to the human anatomy.

The chart below, which is based on data from the U.S. Public Health Service's Agency for Toxic Substances and Disease Registry (ATSDR), as published in the IIAR Ammonia Data Book, shows the effects of various concentrations of ammonia.

Concentration	**Effect**
5 ppm	Average odor threshold (well below harmful health effects)[3]
100-200 ppm	Irritated eyes[4]
300 ppm	Respiratory Protection Required above this level- IDLH[2]
400 ppm	Immediate throat irritation[3]
500 ppm and below	No permanent eye damage to even chronic exposure[4]
1,700 ppm	Cough[3]
2,400 ppm	Threat to life after 30 minutes[3]
5,000+ ppm (vapor)	Full body chemical suit required[4]
5,000+ ppm (pure liquid)	Second degree burns with blisters[4]
7,338 ppm	One Hour LC_{50}, lethal concentration (rat)[5]

The self-alarming property of ammonia is recognized by virtually all engineers, designers, technicians and mechanics that deal with and work on ammonia systems regularly. Thus, small leaks are repaired quickly and not neglected or dismissed as insignificant.

Modern ammonia systems are fully contained closed-loop systems with fully integrated controls, which regulate pressures throughout the system. Also, every refrigeration system is required by codes, which are effective, mature and constantly updated and revised, to have safety relief valves to protect the system and its pressure vessels from over pressurization and possible failure. The most accepted method of release for ammonia systems is by venting of the vapor from the relief valves directly into the atmosphere at a safe location. Specific evaluation may be required in order to determine the preferred or most appropriate release method for the site. Ammonia is lighter than air (molecular weight of ammonia is 17, molecular weight of air is 28).

2.4 Environmental Aspects

Ammonia is not a contributor to ozone depletion or global warming[6].

Thus, it is an environmentally benign refrigerant. Ammonia has no cumulative effects on the environment and a very limited (a few days[7]) atmospheric lifetime. Because of the short lifetime of ammonia in the atmosphere, it is considered to be biodegradable. It is even used to reduce harmful stack gas emissions by injection into boiler and gas turbine exhaust streams. In such systems, only part of the ammonia is consumed in the emission control process, and a small fraction is released into the environment.

Ammonia may be released to the atmosphere by sources such as decaying organic matter, animal excreta, fertilization of soil, burning of coal, wood, etc., and by volcanic eruptions. Ammonia may be released into water as effluent from sewage treatment and/or industrial processes and as run-off from fertilized fields or areas of livestock concentrations. Ammonia may be released into soils from natural or synthetic fertilizer applications, livestock excrement, the decay of organic material from dead plants and animals or from the natural fixation of atmospheric nitrogen.

2.5 Considerations of Ammonia as a Refrigerant

While the benefits of ammonia as a refrigerant are well known, (high energy efficiency, zero ODP, zero GWP, low TEWI or excellent LCCP, self-alarming pungent odor) barriers to expanding its use into HVAC&R applications must be addressed. These barriers generally relate to human health and to ammonia refrigeration system installation cost. Ammonia reacts with copper in the presence of common contaminants such as air and water. Therefore, with the exception of some copper containing bronze alloys used in compressor and pump bearings, ammonia systems are constructed using aluminum, carbon steel, and stainless steel components. Joints are most often welded, rather than brazed. A lack of technicians trained to understand and handle ammonia refrigeration systems also presents a barrier to its implementation, especially in markets where ammonia has not traditionally been used.

In properly constructed and commissioned refrigeration systems, ammonia contributes to a high theoretical COP compared to many refrigerants that are currently in use[8]. The high efficiency of ammonia systems also benefits the environment by requiring less energy for a given refrigeration load, and thus less carbon dioxide emissions associated with the production of electricity.

Economic conditions must also be considered when evaluating ammonia as the choice as a refrigerant. Even though the price of refrigerant grade ammonia is comparatively low, under $1/lb in most regions, the installed cost of the equipment may eclipse commercial (i.e. halocarbon and synthetic refrigerant) equipment on a price/capacity comparison. This is primarily due to the industrial nature of ammonia refrigeration equipment with a typical expected lifetime of 40 years or more. When a full Life Cycle Cost analysis is performed, even a relatively small ammonia system has been found to be cost competitive due to the savings in operating costs and other long term benefits from the rugged equipment design. From a purely economic analysis, without unnecessary regulatory burdens, ammonia should find broader applications as a refrigerant than it currently enjoys.

2.6 Regulatory Classifications

Anhydrous ammonia (Chemical Abstracts Service, CAS #7664-41-7) is currently classified by the U.S. Environmental Protection Agency (EPA) as an extremely hazardous substance (EPCRA, Sec. 302, 303). It is included on the following Emergency Planning and Community Right-to-Know Act (EPCRA)[9] lists:

- Reportable Quantity List (Section 304) -Chemicals on this EPCRA list require notification to EPA and state and local agencies of releases in excess of the reportable quantity (currently 100 pounds).
- Extremely Hazardous Substance List (Section 302) -Chemicals on this EPCRA list, at facilities with quantities in excess of the Threshold Planning Quantity (TPQ), are subject to EPCRA requirements, which mandates numerous reporting and planning provisions. The TPQ of ammonia is 10,000 pounds.
- Section 313 - Chemicals on this EPCRA list are subject to the annual toxic release inventory reporting (Form R).

In the United States the Environmental Protection Agency (EPA) and the Department of Transportation (DOT) reference exposure guidelines designed to help responders deal with emergencies involving an ammonia release or other chemical spills where members of the general public may be exposed to a hazardous airborne chemical. Acute Exposure Guideline Levels (AEGL) are single, non-repetitive exposures that do not exceed (8) eight hours. AEGLs estimate the concentrations at which most people, including sensitive individuals such as old, sick, or very young people will begin to experience health effects if they are exposed to a hazardous chemical for a specific duration.

The Department of Transportation (DOT), in the United States, publishes an Emergency Response Planning Guidebook which references the Emergency Response Planning Guidelines from the American Industrial Hygiene Association (AIHA). Similar to the AEGL guidelines, the ERPG guidelines estimate the concentrations at which most people will begin to experience health effects if they are exposed to a hazardous airborne chemical for more than (1) hour. The DOT guidebook is intended for use by first responders during the initial phase of a transportation incident involving hazardous materials. The AEGL/ERPG values for ammonia are presented below from the DOT Emergency Response Planning Guidebook 2016 Edition.[10]

150 ppm	AIHA/DOT Emergency Response Planning Guidelines (ERPG-2 for up to 60 min.)
160 ppm	EPA/DOT Acute Exposure Guideline Levels (AEGL-2 for up to 60 min.)

While the EPA addresses ammonia from the environmental perspective, the U.S. Occupational Health and Safety Administration (OSHA) addresses ammonia from the perspective of worker safety. OSHA defines ammonia as a hazardous material and, depending on its use, imposes certain regulations on its use, storage, handling and occupational exposure.

Regulatory safety limits for ammonia (as defined in the United States) are presented in the table below:

Concentration	**Health Effect / Regulatory Definition**
25 ppm	NIOSH Time-Weighted Average (TWA)[2]
35 ppm	NIOSH Short-Term Exposure Limit (STEL) [2]
50 ppm	OSHA Personal Exposure Limit (PEL) [2]
150 ppm	Emergency Response Planning Guidelines (ERPG)-2[11]
160 ppm	Acute Exposure Guideline Levels (AEGL)-2[12]
300 ppm	OSHA Immediately Dangerous to Life and Health (IDLH)[13]
15-16,000 ppm	OSHA 10% by volume in air, lower flammable limit (LFL)[14]

The threshold limit value (TLV) consists of two components—the time-weighted average (TWA) concentration and the short-term exposure limit (STEL). The TWA is the time weighted average concentration for a normal eight-hour work day and a 40-hour work week. The STEL is a 15-minute time weighted average exposure that should not be exceeded at any time during the work day, even if the eight-hour TWA is within the TLV. The immediate danger to life or health (IDLH) was set by NIOSH as a 30-minute escape impairment level and it is NOT a lethal concentration. The purpose of IDLH is to establish when the maximum level of respiratory protection is required by OSHA regulations.

The lower explosive limit (LEL) is defined by OSHA as the lowest concentration of ammonia (or other vapors, gas or fumes) required to produce fire in the presence of an ignition source like flame or heat.

In the United States, the Occupational Safety and Health Administration (OSHA) provides guideline limits for worker safety. Limits for the presence of explosive and flammable liquids in the air as well as for the safe storage of these materials to prevent fire and explosion are also defined as shown in the table above. Other regions of the world may define safety and storage limits for ammonia at alternate levels and should be referred to for all design, safety and operating guidelines.

TEPA and OSHA classify all CFCs and HCFCs as hazardous substances, and thus the use of these refrigerants requires specific reporting and management practices comparable to ammonia.

2.7 Risk Assessment

All refrigerating systems require risk assessment; ammonia systems are not exceptions. OSHA's Process Safety Management (PSM), 29 CFR 1910.119, provides guidelines for a comprehensive program developed by employees and management at facilities to ensure that proper safety, maintenance and operating procedures are followed, and thereby minimize potential hazards. This PSM incorporates ANSI/ASHRAE Standard 15, Safety

Standard for Refrigeration Systems[15] as well as other standards for design, installation, maintenance and operation. Although it only affects plants with large refrigerant charges, its requirement for what-if or hazop analyses are directed towards reducing risks and promoting plant safety, so PSM can also be a good program for smaller plants.

Facilities covered by OSHA's PSM are also covered by EPA's Risk Management Program (RMP), which is intended to prevent, detect and respond to accidental releases of hazardous chemicals and to inform local communities of the risks. With an appropriate application of PSM and RMP programs to ammonia refrigeration systems, safety to individuals, communities and the environment is enhanced. However, the application of PSM and RMP programs must be refined and tailored to avoid imposing unreasonable and overly burdensome barriers in new and existing ammonia refrigeration systems.

For facilities with low ammonia charges not covered by OSHA PSM and EPA RMP, the International Institute of Ammonia Refrigeration (IIAR) has developed an Ammonia Risk Management (ARM)[16] plan that can be applied to adhere to OSHA's General Duty Clause which requires employers to provide a safe work environment for their employees.

Regulatory and risk management programs will vary by country and region. Engineers, owners and operators working with ammonia refrigeration systems should review the local regulations to ensure compliance and safety standards are met.

3. RECOMMENDATIONS

3.1 ASHRAE's Strong Position

ASHRAE has a long history of involvement with the use of ammonia as a refrigerant. Ammonia is considered to be an essential refrigerant in industrial and commercial refrigeration and space conditioning due to its high efficiency and environmentally benign characteristics. ASHRAE has a significant role to play in encouraging the proper and safe use of ammonia in the following areas: policy; research, standards, codes and guidelines and technology exchange and education.

ASHRAE will:

- Promote authoritative information on ammonia by seminars and publications.
- Continue research on ammonia topics such as handling, application, operation, control of emissions and new technology.
- Maintain and develop standards and guidelines for practical and safe application of ammonia in industrial and commercial refrigeration, food preservation, indirect space conditioning, heat pump systems, winter sports and other applications. Encourage the broad use of ammonia in traditional and new applications.
- Provide programs and publications of innovative designs and application of ammonia.
- Advise governments and code officials with information regarding ammonia.

3.2 Policy

ASHRAE's Ammonia as a Refrigerant Position Document emphasizes the important role that ammonia can play as an alternative to CFC, HCFC, and other synthetic refrigerants. It also identifies ASHRAE's concerns about the use of ammonia and establishes what the Society will do to encourage and support its proper and safe use as a refrigerant.

Ammonia has been identified by the EPA[17]as a viable alternative to currently used refrigerants because it does not deplete the ozone layer or contribute to global warming. The United Nations Environmental Program (UNEP) has identified ammonia as an excellent refrigerant for replacement of many current CFC and HCFC applications [2010 Technical Options Report] as part of the reassessment of the Montreal Protocol. Other countries have established policies to encourage and promote the use of ammonia indirectly, including the replacement of such HCFC refrigerants as R-22 for applications like water chillers and commercial refrigeration systems for supermarkets.

Other international organizations have issued positions or statements of support for the use of ammonia as a refrigerant. These include the Australian Institute of Refrigeration, Air-Conditioning and Heating (AIRAH)[18], the International Institute of Refrigeration (IIR)[19], the German Institute of Refrigeration (DKV)[20] etc.

3.3 Research

ASHRAE is unique among technical engineering societies because it sponsors an extensive member-supported research program. In 2013-2014, the ASHRAE Board of Directors has approved funding for ASHRAE research projects and grant and aid payments of nearly $3 million. A significant portion of current projects relate to alternative refrigerants, including ammonia. In past years, ASHRAE has promoted several research projects related to various aspects of ammonia refrigeration. The most recent ASHRAE research plan includes a goal to facilitate the use of natural and low global warming potential (GWP) synthetic refrigerants and seek methods to reduce their charge. ASHRAE has had research projects that involve ammonia, including:

- Condensation-Induced Hydraulic Shock Laboratory Study, $81,800 project managed by TC 10.3 at Georgia Institute of Technology (970-RP).
- Evaporation of Ammonia Outside Smooth and Enhanced Tubes with Miscible and Immiscible Oils, $115,675 project managed by TC 1.3 at Texas Tech University (977-RP).
- In-Tube Condensation of Ammonia in Smooth and Enhanced Tubes With and Without Miscible Oil, $147,000 project managed by TC 1.3 at University of Illinois (1207-RP).
- Flow Regime and Pressure Drop Determination for Two-Phase Ammonia Upward Flow in Various Riser Sizes, $215,240 project managed by TC 1.3 at Danish Technical Institute (1327-RP).
- Evaporation in Flooded Corrugated Plate Heat Exchangers with Ammonia and Ammonia/Miscible Oil, $97,585 project managed by TC 10.3 at Ghulan Ishaq Kahn Institute (1353-RP).
- CFD Study of Hydraulic Shock in Two-Phase Anhydrous Ammonia, project managed by TC 10.3 at ASCOMP USA (1569-RP).

ASHRAE encourages the submission of proposals for new research projects related to refrigeration and other applications that use ammonia. Several future ammonia projects are included in the most recent research plan.

3.4 Standards, Codes and Guidelines

ASHRAE plays a major role in development of voluntary standards and guidelines governing the application and use of refrigerants, including ammonia. In addition, other organizations adopt the technical requirements developed by ASHRAE into various codes and regulations.

The most important ASHRAE standards dealing with ammonia are ANSI/ASHRAE Standard 34-2013, Designation and Safety Classification of Refrigerants[21], and ANSI/ASHRAE Standard 15- 2013, Safety Standard for Refrigeration Systems. Standard 34 classifies ammonia as a Group B2L refrigerant, because of toxicity and flammability concerns. Standard 15 establishes the requirements for safely applying ammonia in refrigerating systems. In general, ammonia can be used in unlimited quantities in direct systems for industrial occupancies. However it must be used in indirect (secondary) systems for commercial and public occupancies. Its general use in small absorption equipment is unrestricted in the United States.

The ASHRAE Refrigeration Handbook states that there is renewed interest in ammonia for HVAC systems because of the scheduled phaseout and increasing costs of HCFC and CFC refrigerants. While ammonia is inappropriate for direct systems, the use of secondary systems that use ammonia to chill water or another secondary refrigerant are a viable alternative to halocarbon systems for HVAC applications[22].

Other technical organizations have issued standards/ guidelines addressing the proper application of ammonia as a refrigerant. These standards/guidelines cover the design, installation and operation of ammonia refrigeration systems [ANSI/ IIAR 2-2014, ANSI / IIAR 4-2015, ANSI / IIAR 5-2013, ANSI / IIAR 7-2013].[23-26] International standards also address safety and application of ammonia [ISO 5149, Refrigeration Safety[27]; ISO 1662, Refrigerating Plants – Safety Requirements[28]; CEN EN 378, Refrigerating Systems Safety and Environmental Requirements[29]].

The proper application of ammonia as a refrigerant is governed by state and local building, mechanical and electrical codes. In the U.S., these codes are issued by various model code organizations such as International Code Council (ICC) and National Fire Protection Association (NFPA). Because of its classification as a hazardous chemical, ammonia is often specifically covered by various requirements in fire codes. The Code Interaction Subcommittee of ASHRAE's Standards Committee will review proposed fire and mechanical codes that could affect refrigeration applications. ASHRAE has established a policy to encourage adoption of ASHRAE standards in model codes.

Electrical codes, especially the National Electric Code[30], are relevant to ammonia because ammonia in high concentrations can form flammable mixtures with air. Standard 15 and ANSI / IIAR 2-2014 establishes design procedures for applying ammonia, including proper ventilation levels, which are referenced in electrical codes to assure the safe application in buildings. Code requirements may vary in other countries and regions; please consult local regulations.

The advent of low charge, packaged ammonia systems will require code organizations to make provision for their application. Some standards, such as IIAR 2 2014, have started to address this, however further work is required from all code organizations to ensure that this new technology can be used to its full potential.

In some cases, very stringent local toxic gas ordinances have been applied to ammonia, even though they were intended to apply to highly toxic chemicals. These types of ordinances can be very restrictive.

3.5 Technology Transfer and Education

ASHRAE plays a very important role in providing technical information on the proper application of ammonia as a refrigerant. In this role, ASHRAE assists in transfer of technology and in education of the technical community. These important activities are carried out through a number of vehicles: ASHRAE Handbook, ASHRAE Journal and ASHRAE Transactions; special publications; and through a number of educational forums.

A major source of technical information on ammonia is the ASHRAE Handbook. The 2013 Fundamentals[31] volume contains general information on Thermodynamics and Refrigeration Cycles (Chapter F2) and on Refrigerants (Chapter F29), including the thermodynamic properties of ammonia. Another major resource for information on ammonia is the 2014 ASHRAE Handbook—Refrigeration[32], covering Liquid Overfeed Systems (Chapter R4), Ammonia Refrigeration Systems. (Chapter R2) and Refrigeration System Chemistry (Chapter R6). An additional resource is the ASHRAE publication Thermophysical Properties of Refrigerants [2013][33].

ASHRAE has published a number of technical papers, articles and special reports addressing the use of ammonia. These include notices and articles regarding ammonia refrigeration in ASHRAE Journal. Technical papers presented at ASHRAE meetings are published in ASHRAE Transactions, and in various special publications. A summary of more than 30 technical articles and references can be found on ASHRAE Online.

Key parts of ASHRAE's technology exchange and education functions are fulfilled by the Annual and Winter Conference technical programs, including seminars, forums, symposia and technical sessions. In addition, the Society offers a self-directed learning course on the Fundamentals of Refrigeration. Local ASHRAE chapters also sponsor refrigeration-related programs and speakers, which have recently shown a strong interest in ammonia.

Technical activities focusing on ammonia are addressed within ASHRAE by the Refrigeration Committee, which is now a standing committee. In addition to the Refrigeration Committee, the Chapter Technology Transfer Committee (CTTC) encourages grass roots regional and chapter activities, which focus on refrigeration. The Refrigeration Committee maintains a speakers list of speakers/topics that includes ammonia. Various technical committees (TCs 10.1, 10.3, 10.5, 1.3, 8.5 etc.) also focus on ammonia-related issues.

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ASHRAE Position Document on Refrigerants and their Responsible Use

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HISTORY OF REVISION/REAFFIRMATION/WITHDRAWAL DATES

The following summarizes this document's revision, reaffirmation, or withdrawal dates:

1/25/2012—BOD approves Position Document titled *Refrigerants and their Responsible Use*

7/2/2014—Technology Council approves reaffirmation of Position Document titled *Refrigerants and their Responsible Use*

Note: ASHRAE's Technology Council and the cognizant committee recommend revision, reaffirmation, or withdrawal every 30 months.

ABSTRACT

Refrigeration and air conditioning provide many benefits to society, but these benefits carry environmental and societal consequences. Many of these consequences stem directly from the refrigerant chosen for each application. ASHRAE has a direct interest in this issue because the operation of refrigerating and air-conditioning equipment depends on refrigerants. Environmental concerns have caused ozone-depleting potential, global warming potential, energy efficiency, and life-cycle climate performance to become important factors. This often results in conflicts between choices: if a lower global warming potential (GWP) refrigerants less efficient than the fluid which it replaces, any direct global warming benefit maybe offset by increased energy consumption. ASHRAE's position is that the selection of refrigerants and their operating systems be based on a holistic analysis of multiple criteria. ASHRAE promotes responsible use of refrigerants and supports the efforts to advance technologies that minimize impact on the environment while enhancing performance, cost effectiveness, and safety.

Note: ASHRAE position documents are approved by the Board of Directors and express the views of the Society on a specific issue. The purpose of these documents is to provide objective, authoritative background information to persons interested in issues within ASHRAE's expertise, particularly in areas where such information will be helpful in drafting sound public policy. A related purpose is also to serve as an educational tool clarifying ASHRAE's position for its members and professionals, in general, advancing the arts and sciences of HVAC&R.

CONTENTS

ASHRAE Position Document on Refrigerants and their Responsible Use

EXECUTIVE SUMMARY

"Refrigerants are the working fluids in refrigeration, air-conditioning, and heat-pumping systems. They absorb heat from one area, such as an air-conditioned space, and reject it into another, such as outdoors, usually through evaporation and condensation, respectively."

–ASHRAE Handbook—Fundamentals[1]

Refrigeration and air conditioning provide many benefits to society, but these benefits carry environmental and societal consequences, many of which stem directly from the refrigerant chosen for each application. This document represents ASHRAE's position on the selection and management of refrigerants.

Throughout the history of air conditioning and refrigeration, numerous substances have been used as refrigerants. However, choosing a refrigerant has become more complex in recent years. Earlier generations of refrigerants—chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)—contributed to the depletion of stratospheric ozone and are being phased out under international treaty. CFCs and HCFCs largely have been replaced with hydrofluorocarbons (HFCs). Some of these HFCs have high global warming potentials (GWP) and are becoming subject to use restrictions in some European countries as the world deals with global climate change. Recently, lower GWP HFCs (referred to as hydrofluoroolefins or HFOs) have been introduced. They have zero ozone depleting potential (ODP) and very low GWP, but some of them are mildly flammable.

Natural refrigerants include ammonia, carbon dioxide, hydrocarbons, water, and air. Some of the natural refrigerants have been used in the market place for many decades although at varying degrees of application. Although environmentally superior favorable, natural refrigerants are not free of other concerns, such as corrosion, toxicity, high pressures, flammability, or in some cases lower operating efficiencies.

In addition, the energy that refrigeration systems consume is often produced from fossil fuels which results in emissions of CO_2, a contributor to global climate change. This indirect effect, associated with electrical generation, frequently presents larger environmental carbon footprint impact than the direct effect of refrigerant emissions.

ASHRAE's position is that the selection of refrigerants and their operating systems be based on a holistic analysis of multiple criteria. The criteria must include energy efficiency, system performance, potential impact on community safety, risk to personal safety, and minimization of direct and indirect environmental impacts. Additionally, the economic and social impacts of any fluid should also be considered. Technical and operational efforts to prevent refrigerant emissions must continue to be developed and implemented.

ASHRAE encourages and supports the ongoing effort to develop new refrigerants and improve the application of existing refrigerants to meet these criteria.

ASHRAE is committed to being a leader in the research to develop and advance HVAC&R technologies that enhance performance and safety and minimize negative environmental impact as well as the development of guidelines and standards to reduce direct and indirect emissions while improving energy efficiency.

1. ISSUES

Choosing a refrigerant for a given application has become more complex in recent years. Flammability and toxicity requirements are covered by the ASHRAE safety standards (Standard 15[2], Standard 34[3]) and their international equivalents (ISO 5149[4], ISO 817[5]), and environmental concerns have caused ozone depleting potential (ODP), global warming potential (GWP), energy efficiency, and life cycle climate performance (LCCP) to become important factors for consideration. Some countries have developed regulatory constraints, international protocols, or voluntary agreements in response. Although, conflicts may occur as a result of choices made. For example, if a lower GWP refrigerant is less efficient than the fluid it replaces then any direct global warming benefit maybe partially or totally offset by increased energy consumption. Since the implementation of the 1987 Montreal Protocol, fluids containing chlorine (e.g., CFC-11, CFC-12, HCFC-22, R-502, HCFC-123) have been restricted due to their ODP, resulting in the transition to alternatives such as hydrofluorocarbons (HFCs) and “natural refrigerants”. Figure1 shows how the use of refrigerants is evolving.

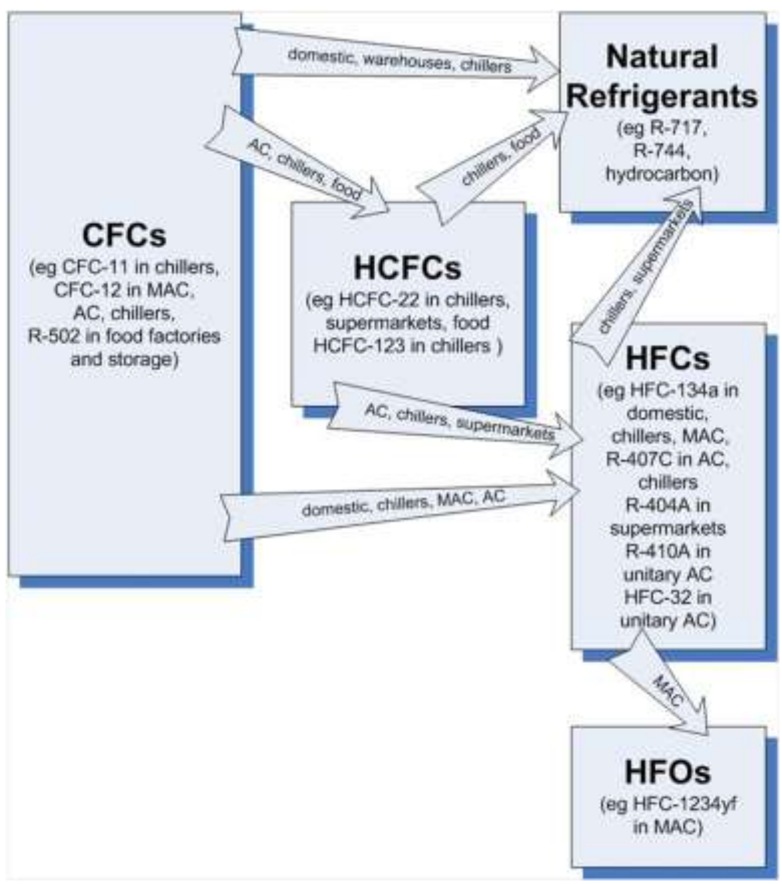

Figure 1 **Map of Refrigerant Change.** This map shows some of the routes that are being taken in the phase-out of CFCs and HCFCs. The process is moving at different speeds around the world: In some countries CFCs are already prohibited, in others their use is in decline as these countries move to complete prohibition. At present, the refrigerants that are likely to be used in the future are the natural refrigerants, the HFCs, the unsaturated HFCs (also known as HFOs), and possibly blends of these refrigerants.

The shift from CFCs was relatively rapid in the developed countries and has been more measured in the developing world. Metrics such as LCCP have been developed to enable comparisons between fluids [6]. (The LCCP methodology includes the environmental impact from the energy used by the refrigeration/air-conditioning system during its lifetime and the life cycle environmental impact of the system's refrigerant.) As such, LCCP can be used as an environmental assessment approach to compare alternative systems. In addition, systems are being designed to reduce the refrigerant charge, and procedures and equipment are being developed to monitor and minimize refrigerant leaks. The emphasis on corporate social responsibility (CSR) from end-users and manufacturers has led to an increased focus on energy efficiency and in some cases, an expressed preference for natural refrigerants. As a result, safety standards have been reassessed and are being updated to reflect the increasing interest in flammable or mildly flammable working fluids.

While each class of refrigerants has favorable performance and/or environmental aspects, none provide an ideal solution. Issues with natural refrigerants include flammability, toxicity, high pressures, or, in some cases, lower operating efficiencies, depending on the fluid. Concern about the high GWP of some HFCs has recently led to calls for a reduction in their use. This is spurring research to extend lower-GWP HFCs into new applications. The reduction has been proposed as a phase-down, however no country has formally adopted a proposal nor is it currently included in either the Kyoto or the Montreal Protocols. At the present time, some hydrofluoroolefins (HFOs) are available in limited quantities, but they are not yet fully tested in all applications. In addition, some HFOs and lower-GWP HFCs have mild flammability. Research is also investigating blends across these refrigerant classes to identify combinations that may optimize performance and minimize negative aspects.

End-of-life disposal of refrigeration and air-conditioning systems is another important issue. At that time, refrigerant should be recovered and recycled or disposed of safely to prevent loss of the charge to the atmosphere.

2. BACKGROUND

Refrigeration and air conditioning provide a broad range of benefits to society, including the preservation of food, comfort conditioning of living spaces and workplaces, and temperature control of industrial processes. The vast majority of refrigeration and air-conditioning equipment operates via the application of the vapor-compression cycle, and such cycles require a working fluid or refrigerant to operate. Refrigerants are thus at the heart of most modern refrigeration and air-conditioning equipment, and the careful selection of refrigerant has a significant impact on the safety, reliability, and energy consumption of the equipment.

A refrigerant must satisfy a number of requirements related to safety, chemical stability, environmental properties, thermodynamic characteristics, and compatibility among materials. There is no single setoff optimum characteristics (especially for thermodynamic properties), and often there are tradeoffs among desirable characteristics. Thus, a variety of refrigerants having a range of properties is needed to meet the requirements of various applications.

A broad range of fluids has been used as refrigerants over the years, and current usage is dominated by a range of fluorinated chemicals, known as HFCs, in addition to hydrocarbons and several inorganic compounds, including ammonia and carbon dioxide (CO_2). An earlier generation of refrigerants, the chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) contained chlorine, and environmental impacts related to ozone depletion resulted in the scheduled phase out of the CFC and HCFC refrigerants under the Montreal Protocol. And now, global climate change concerns have focused attention on the HFC refrigerants; in some countries, the HFCs are facing restrictions in certain applications.

The net climate impact of a refrigerant is dependent on direct and indirect effects. The direct effect is from the global warming impact of a refrigerant emitted to the atmosphere (either from a leak, accident, or from improper handling or disposal). The indirect effect is associated with the energy consumed during the operation of the heating, ventilating, air-conditioning, and refrigerating (HVAC&R) equipment. This indirect effect, which occurs as a result of the CO_2 produced from fossil fuel power plants, is usually much greater than the direct effect due to the GWP of the refrigerant itself. The refrigerant is contained within a sealed system and should not be emitted to the atmosphere at all under normal operation and with proper end-of-life disposal. In actual practice, systems are subject to leakage and breaks and require proper maintenance to minimize losses. Both direct and indirect effects are considered in metrics such as the total equivalent warming impact (TEWI)[7] and LCCP[6]. The total climate impact of a refrigeration system may increase in switching to a lower-GWP refrigerant if the energy efficiency is lower.

A more thorough discussion of the history of refrigerants, the classes of refrigerants and their attributes and tradeoffs, and means of mitigating risks associated with different classes of refrigerants is presented in the Appendix of this document.

2.1 ASHRAE Activities

ASHRAE has a direct interest in this issue because the operation of much of the heating, refrigerating, and air-conditioning equipment depends on refrigerants. ASHRAE contributed to the successful effort to phase out the ozone-depleting CFC and HCFC refrigerants, and it has a significant role to play in encouraging the proper and safe use of refrigerants going forward. ASHRAE is active in the following areas: policy, research, standards, codes and guidelines, and technology transfer and education.

ASHRAE plays a major role in the development of voluntary standards and guidelines governing the application and use of all types of refrigerants. Other organizations adopt the technical requirements developed by ASHRAE into various codes and regulations. The most important ASHRAE standards dealing with refrigerants are ANSI/ASHRAE Standard 34, *Designation and Safety Classification of Refrigerants* [3], ANSI/ASHRAE Standard 15, *Safety Standard for Refrigeration Systems* [2], and ANSI/ASHRAE Standard 147, *Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment* [8].

ASHRAE plays an important role in providing technical information on the proper application of refrigerants and in educating the technical community. These activities are carried out through handbooks, journals, technical meetings, special publications, and educational training. Local ASHRAE chapters also host refrigerant-related programs and speakers. Technical activities in this area are addressed within ASHRAE by the Refrigeration Committee, by committees responsible for the maintenance and revision of the Standards mentioned above, and by numerous technical committees.

ASHRAE is unique among technical engineering societies in sponsoring an extensive member-supported research program. The 2010–2015 research plan for the Society includes items to facilitate the application of low-GWP refrigerants, to investigate methods to reduce refrigerant charge in systems, and to improve system efficiency.

A major focus of ASHRAE's activities is on improving the energy efficiency of buildings. Reducing the heating and cooling load of buildings implies smaller HVAC&R systems with smaller charges of refrigerant and smaller indirect climate impacts resulting from energy generation.

3. RECOMMENDATIONS

ASHRAE acknowledges that HVAC&R systems have environmental consequences and ASHRAE is committed to making these systems more sustainable. Because of their environmental impacts, ASHRAE holds to the principle that refrigerants should be used prudently to provide best value to society.

3.1 ASHRAE's Strong Position

ASHRAE holds a strong position that:

- selection of refrigerants and their operating systems be based on a holistic analysis including energy efficiency and performance attributes; environmental impacts; community and personal safety; and economic considerations (e.g., a refrigerant should not be selected based on any one single factor such as GWP, operating pressure, flammability, etc., a variety of refrigerants are required to meet the range of HVAC&R applications);
- the HVAC&R industry should comply with all applicable regulations;
- refrigerant emissions should be reduced through research, education, improved design and maintenance procedures, and enforcement;
- at the end equipment life, all refrigerants should be recovered for reuse, reclamation or destruction

3.2 ASHRAE's Research Recommendations

ASHRAE recommends that further research be conducted on:

- balancing the safety, energy efficiency, cost, and environmental impact for refrigerants using a consistent and comprehensive methodology across all refrigerants and system types using benchmarks like LCCP, life cycle assessment (LCA) or TEWI;
- advancing the design and development of refrigeration and air conditioning equipment that facilitate reduced refrigerant emissions
- developing methodologies and practices to minimize or prevent refrigerant loss during installation, operation, maintenance, and decommissioning of refrigeration systems;
- developing tools, equipment, and approaches to identify, and thus minimize, refrigerant emissions during system operation
- developing new refrigerants that minimize environmental impacts and safety concerns

3.3 ASHRAE's Commitment

ASHRAE is committed to:

- supporting research to develop and advance HVAC&R technologies that minimize impact on the environment while enhancing performance, cost effectiveness, and safety;
- supporting development of guidelines and standards to improve energy efficiency and to reduce refrigerant emissions;
- supporting responsible refrigerant use through education, information dissemination, and proper technician training;
- being a leader of those dedicated to advancing responsible refrigerant use by working with societies, universities, and government agencies
- promoting responsible use of refrigerants

APPENDIX—BACKGROUND

Refrigeration and air conditioning provides a broad range of benefits to society, including the preservation of food, comfort conditioning of living spaces and workplaces, and temperature control of industrial processes.

The vast majority of refrigeration and air-conditioning equipment operates by application of the vapor-compression cycle wherein a working fluid, i.e., a refrigerant, is alternately compressed and condensed (releasing heat) and then expanded and evaporated (absorbing heat) thereby transferring heat from a low-temperature volume (e.g., a refrigerator) to a higher-temperature volume (such as ambient air). The same process can be used as a heat pump to extract low-temperature heat from an ambient source and "upgrade" it to provide heating. These processes require the input of work (usually in the form of electricity) to drive the compressor and auxiliary fans and pumps. Vapor-compression equipment is responsible for a significant portion of total global energy consumption.

Refrigerants are thus at the heart of most modern refrigeration and air-conditioning equipment, and the careful choice of the refrigerant has a significant impact on the safety, reliability, and energy consumption of the equipment.

History of Refrigerants

Mechanical refrigeration based on the vapor compression cycle was first demonstrated in the 1830s and for the next century a broad range of substances were used; these included toxic compounds, such as sulfur dioxide, as well as refrigerants still in widespread use, such as ammonia. Calm and Hourahan[9,10] characterized this "first generation" of refrigerants as "whatever worked." The widespread adoption of home refrigerators in the 1930s spurred the development of nonflammable and low-toxicity refrigerants, and the CFC (chlorofluorocarbon) and later HCFC refrigerants dominated this "second generation" of fluids.

Ozone Issue and the Montreal Protocol

CFCs and HCFCs contain chlorine, and chlorine in the stratosphere (the region of the atmosphere between about 10 and 50 km above the surface) was established as one of the primary causes of the depletion of stratospheric ozone which led to the formation of the Antarctic ozone hole each spring, along with smaller losses at high latitudes in both hemispheres. Ozone absorbs harmful ultraviolet radiation from the sun, protecting the earth's surface. The mere presence of chlorine in a molecule is not sufficient to threaten stratospheric ozone—the molecule must first be released to the atmosphere and then remain intact in the atmosphere sufficiently long for it to be transported to the stratosphere. A metric termed the ozone depletion potential (ODP) quantifies the destructive effect on ozone of a chemical released to the atmosphere relative to that of CFC-11, which is assigned an ODP value of 1.

On all counts, the properties and usage of the CFC and HCFC refrigerants combined to make them significant contributors to ozone depletion. They contain chlorine. They were relatively inexpensive chemicals and thus there was little incentive to fix leaks or recover them from equipment, leading to emissions to the atmosphere. They have significant atmospheric lifetimes—on the order of decades to centuries.

In response to this environmental concern, the Montreal Protocol on Substances That Deplete the Ozone Layer was adopted in September 1987 under the auspices of the United Nations and entered into force January 1, 1989.It has now been ratified by every member country of the United Nations. The original Protocol called only for a 50% phasedown of the CFCs, but subsequent changes to the Protocol mandate a complete phase out of both the CFC and HCFC refrigerants.

One of the initial responses to the Montreal Protocol was to transition certain applications of CFCs to HCFCs, which have ODP values that are significantly lower than CFCs, although not zero. The transition to HCFCs was recognized as an interim measure and allowed for a rapid phase out of the more detrimental CFCs. Concurrently, a range of HFCs (which have ODPs of zero) and blends of HFCs were developed to meet the requirements of most refrigeration applications. In addition, increased attention was given to reducing emissions from refrigeration equipment and recovering refrigerant during servicing and at disposal; in some cases these are mandated by regulations.

Although the primary purpose of the Montreal Protocol was to protect ozone, it also resulted in a large reduction in greenhouse gas emissions. This is because the CFCs were, as a class, much more potent greenhouse gases than the HFCs that replaced them. The IPCC reports: “In 2010, the decrease in annual ODS emissions under the Montreal Protocol is estimated to be about10 gigatonnes of avoided CO_2-equivalent emissions per year, which is about five times larger than the annual emissions reduction target for the first commitment period (2008–2012) of the Kyoto Protocol.” [11].

Global Climate Change: The Kyoto Protocol and F-Gas Legislation

The HFCs are greenhouse gases due to their absorption of infrared (heat) radiation. CO_2 also absorbs IR radiation, but an HFC molecule is more effective than a molecule of CO_2 in contributing to climate change in part because HFCs absorb at wavelengths where the atmosphere is otherwise largely transparent. A metric termed the “global warming potential” or GWP quantifies this effect; GWP values are relative to CO_2, which is assigned a GWP value of 1. This is a time-dependent process, and an “integration time horizon” must be defined for every GWP value; a 100-year time horizon is most commonly used (GWP_{100}).

In response to the impacts that global climate change would have on human societies and the global ecosystem, the United Nations Framework Convention on Climate Change (UNFCCC) was develop data summit held in Rio de Janeiro in June 1992.The UNFCCC did not set limits on greenhouse gases but did provide for updates (or “protocols”) that would mandate limits. The first of these was the Kyoto Protocol, which was adopted December 1997 and entered into force in February 2005. The Kyoto Protocol has been ratified by 191 nations; the United States signed the Protocol but has not ratified it. The Protocol set limits for developed countries only for four greenhouse gases (CO_2, methane, nitrous oxide, and SF_6) and two groups of gases (perfluorocarbons and hydrofluorocarbons); emissions of these gases were converted to their CO_2 equivalent (using GWP values), and the emission limits for a given country were in terms of the total CO_2 equivalent. The CFCs and HCFCs were not included because a phaseout of these chemicals was already mandated by the Montreal Protocol. Thus, under the Kyoto Protocol, there are no specific mandates for reductions or phase out of the HFCs or any other refrigerants.

The climate impact of refrigeration equipment is much larger than the direct global warming impact of a refrigerant emitted to the atmosphere (either from a leak, accident, or from improper handling or disposal). Refrigeration equipment consumes energy during its operation, and when this energy is produced by fossil fuels, CO_2 is produced. In some applications, this "indirect" effect of producing energy is much greater than the direct effect due to the GWP of the refrigerant itself. The refrigerant is contained within a sealed system and should not be emitted to the atmosphere at all under normal operation and with proper end-of-life disposal. In actual practice, systems are subject to leakage and accidents and require proper maintenance to minimize losses.

The concept of total equivalent warming impact (TEWI)[7] was developed to include both direct and indirect impacts of refrigeration systems. This has been modified to the LCCP through addition of the (direct and indirect) impacts from refrigerant and component manufacturing. Both TEWI and LCCP are much more complicated metrics than the direct GWP of the refrigerant itself. They must include (and make assumptions about) the energy efficiency of equipment, local CO_2 equivalent of energy generation, system charge, emission rates during operation, average lifetime of equipment, and the recovery (or not) of refrigerant from equipment prior to disposal. TEWI and LCCP values are thus specific to a particular application and may differ from region to region.

HFCs, in all applications, presently contribute only about 2% of the total anthropogenic warming[12]. However, HFC emissions are increasing due to the last of the CFC-and HCFC-based equipment being replaced with HFCs and the increased use of air conditioning worldwide. Assuming "business as usual" with regards to refrigeration and a significant replacement of fossil fuels with renewable energy, the HFCs could account for a significant fraction of total GHG emissions (on a CO_2 equivalent basis) by the middle of the century[13]. This concern has resulted in the European Union enacting regulations covering HFCs, perfluorocarbons, and SF_6 in all their applications. This so-called F-Gas Legislation provides for inspection, recovery, reporting, and training requirements when these gases are used in all but small refrigeration systems. The associated Mobile Air-Conditioning Directive bans the use of HFC-134a in new vehicle models beginning in 2011 and in all new vehicles beginning in 2017.This Directive also requires that the replacement refrigerant must have a GWP_{100} less than 150.

In 2010, the United States co-sponsored (with Canada and Mexico) a proposed amendment to the Montreal Protocol that would phase down by 2033 the use of HFCs to 15% of the combined 2005–2008 consumption of HFCs plus 85% of HCFCs based on GWP weightings[14]. This proposal explicitly recognizes that there are not alternatives for all HFC applications and therefore calls for a phasedown as opposed to a phaseout. The baseline includes HCFCs due to the continuing transition from HCFCs to HFCs. Although the Montreal Protocol addressed ozone depletion, it resulted in a universally accepted program for restrictions on refrigerants, and thus provides a mechanism for including HFCs. A total of 91 countries signaled their readiness to regulate HFCs through the Montreal Protocol by signing a declaration that recognized that the projected increase in the use of HFCs poses a major challenge for the world's climate system.

These developments have led to renewed and increased interest in natural refrigerants and the development of new low-GWP options, as discussed in following sections.

Requirements of a Refrigerant

A refrigerant must satisfy a number of (sometimes conflicting) requirements as discussed by McLinden and Didion[15].The most essential requirement is chemical stability; a refrigeration system is expected to operate many years, and all other properties would be meaningless if the refrigerant decomposed or reacted to form something else. The next most important criteria relates to health and safety; the ideal refrigerant would have low toxicity and be nonflammable. ASHRAE Standard 34[3] classifies refrigerants according to their toxicity (with “A” being a “lower degree of toxicity” as indicated by a “permissible exposure limit” of 400 ppm or greater, while “B” refrigerants have a “higher degree of toxicity”) and flammability (ranging from “1” for nonflammable fluids to “3” for highly flammable fluids, such as the hydrocarbons). Flammability class“2” has a further subclass (“2L”) for refrigerants of very low flammability, as defined by a burning velocity of less than 10 cm/s. Thus, an ideal refrigerant would be class “A1,” and such refrigerants can be used with minimal health and safety restrictions. Other classes are restricted, such as maximum limits on the system charge or restriction to use in dedicated machine rooms. Such restrictions are enunciated in mechanical codes, many of which are based on ASHRAE Standards 34[3] and 15[2] and corresponding international standards, such as ISO/FDIS 817[5] and ISO/FDIS 5149[4].

Another important set of criteria relate to the performance (i.e., energy efficiency and capacity) of a system. The thermodynamic characteristics (most importantly normal boiling point, critical temperature, and heat capacity) must be matched to the application for the system to operate efficiently. Here there is no single set of optimum values, and a variety of refrigerants having a range of properties is needed to meet the requirements of various applications. Favorable transport properties (low viscosity and high thermal conductivity) have an impact on the size of the heat exchangers and thus cost of the overall system. Energy efficiency, along with the ozone depletion potential and global warming potential are key environmental criteria. Environmental impacts related to ozone depletion drove the phase out of the CFC and HCFC refrigerants. Global climate change concerns have focused attention on the HFC refrigerants. The atmospheric lifetime of a refrigerant affects both ODP and GWP; low values are associated with short atmospheric lifetimes. Here there is often a direct conflict between the need for chemical stability (within the sealed refrigeration system) and the need for chemical breakdown if a refrigerant is released to the atmosphere.

A final set of practical criteria relate to materials and impact the long-term reliability of a system. The refrigerant must be compatible with common materials of construction, including metals and seals. A suitable compressor lubricant must be available.

Classes of Refrigerants

Hydrocarbons and Inorganic Compounds

These include ammonia, CO_2, simple hydrocarbons, and water; they are often referred to as “natural refrigerants.” (Although these molecules are found in nature, generating sufficient quantities for refrigeration requires industrial separation processes or, in the case of ammonia, industrial synthesis.) They have zero ODP and low GWP values. There has been increased interest and application of these refrigerants in recent years, although all of these fluids present one or more drawbacks (such as toxicity, flammability, corrosivity, high pressures, and/or lower efficiency) that require consideration when designing systems.

Ammonia has been used as a refrigerant for more than 150 years. It has excellent thermodynamic characteristics and provides a very high refrigeration effect per mass, but the volumetric cooling capacity is similar to many halocarbon refrigerants. It also has a very high discharge temperature from the compressor, and this has to be taken into account when designing systems. It is applicable to a wide range of cold-side temperatures. Ammonia has a toxicity classification of B according to ASHRAE Standard 34 [3] and has an ASHRAE flammability rating of 2L. It is not compatible with copper and copper alloys.

Ammonia is very common in large beverage processing, food storage, and industrial refrigeration systems where its thermodynamic characteristics and low cost outweigh the regulatory burdens. Interest in small ammonia systems has increased in recent years, and compressors and other components compatible with ammonia are commercially available. For additional information see the ASHRAE Position Document on Ammonia as a Refrigerant [16].

Absorption chillers with ammonia/water mixture are suitable and cost effective for some specific applications, especially using a waste heat, in Combined Chilling, Heat and Power (CCHP) systems and district cooling.

Ammonia used in refrigeration is produced as anhydrous ammonia for fertilizer. Ammonia has a production process has a carbon equivalent of 2 kg CO_2 eq per kg[17].

$CO_2$is nonflammable and has low toxicity; its ODP is zero, and it has a $GWP_{100}$of one; it has an ASHRAE classification of A1. The pressure/temperature characteristics of CO_2, however, have two major implications for refrigeration system design. First, it operates at very high pressures, approximately ten times the pressure of halocarbon or ammonia systems. Second, the low critical temperature of 31.0 ˚C implies a trans-critical cycle in many applications requiring direct heat exchange with the outdoor environment. While transcritical operation may lead to low operating efficiency at higher ambient temperatures in cooling mode, a trans-critical cycle, with its gliding temperature across the condenser gas cooler, can increase the efficiency of applications such as water-heating heat pumps that have gliding temperatures of the sink fluid. The high operating pressure simply a dense refrigerant that requires smaller piping and compressor sizes and reduced penalties from pressure drops can yield operation and design benefit particularly when evaporator temperatures drop to the -30 to -50°C..

CO_2 has been used as a refrigerant since the mid-19th century, but was largely displaced by ammonia and the CFC and HCFC refrigerants by the mid-20th century. There has been a resurgence of interest since the early 1990s as an alternative to the halocarbon refrigerants. It is being used in heat pump water heater applications (primarily in Japan). CO_2 is experiencing high growth in supermarket refrigeration systems either in a transcritical cycle or in the low-temperature stage of a cascade system that allows this refrigerant to operate in a sub-critical mode (i.e. a normal vapor-compression cycle). CO_2 is also being used as the heat-transfer fluid in secondary heat-transfer loops (also termed “pumped CO_2”).

The carbon dioxide used as a refrigerant is generally of industrial or scientific grade, and is typically recovered from the waste streams of industrial processes. The embedded energy required to reclaim, clean, liquefy and transport carbon dioxide is estimated to have a carbon equivalent of 1 kg CO_2 eq per kg [17].

Hydrocarbons are constituents of natural gas and petroleum. The most common hydrocarbon refrigerants are propane, butane, and isobutane. They generally have good thermodynamic properties. Hydrocarbons with a wide range of boiling points are available to meet refrigeration requirements over a wide range of temperatures. These refrigerants have zero ODP, low GWP, and are generally of low toxicity. However, they are highly flammable, and this is the major impediment to their wider use.

Hydrocarbons have long been used for process refrigeration in the petrochemical industry; here flammability of the refrigerant is not an issue because the products being produced are of similar hazard. Household refrigerators using isobutane as the refrigerant were introduced in Europe in1992 and now account for more than one-third of global production. The growth of hydrocarbons as refrigerants is rapid in China and India, countries with high GWP tax on refrigerants (Australia) are also adding hydrocarbons to mainstream use. The growth of hydrocarbons is limited by the current state of safety training for service personal and the additional costs involved in flammability safety mitigation.

Hydrocarbons used as a refrigerant are generally of industrial or scientific grade. They are recovered from the natural gas industry and the embedded energy required to clean, liquefy and transport are less than a carbon equivalent of 1 kg CO_2 eq per kg [17].

Water could be considered the ultimate in safe and environmentally benign refrigerants, but it has a very low vapor density, requiring large compressor and piping sizes. Pressure drops across components extracts a larger efficiency penalty compared to higher-pressure equipment. The equipment operates under a vacuum posing the problem of drawing air into a system. Development of prototype vapor-compression equipment using water is underway for large chilled-water systems (such as those used in large building air-conditioning).Water is used in absorption-type refrigeration equipment (with lithium bromide as the absorbent), but this type of refrigeration cycle has low energy efficiency and is typically used only when a waste heat source is available at very low cost. The lower temperature limit for water is 0˚C.

Halocarbon Refrigerants

The halocarbon refrigerants include one or more of the halogens (i.e., the elements fluorine, chlorine, or much less frequently, bromine or iodine) in a molecule with a carbon backbone. These chemicals were first commercialized in the 1930s and include CFCs (i.e., containing carbon, fluorine, and chlorine), HCFCs (also containing hydrogen), and HFCs (which do not contain chlorine).

The most commonly used CFCs used CFC refrigerants were CFC-12 and CFC-11. CFC-12wasusedinamultitudeof applications ranging from automotive air conditioning and various refrigeration applications to large centrifugal water chillers. It possessed very good performance characteristics and was widely available and affordable. The refrigerant application of CFC-11 was in low-pressure centrifugal chillers. As discussed previously, the production of these refrigerants was phased out by year end 1995 in developed countries and by year end 2009 in developing countries due to their impact on stratospheric ozone.

The most common HCFC is HCFC-22. It was extensively employed in a wide array of stationary air-conditioning systems that ranged from small window units, ducted and duct-less split systems, to large screw water chillers and even some very large centrifugal chillers. It also found use in a number of refrigeration applications from walk-in coolers/freezers to large industrial refrigeration systems. It performs well over a wide range of application temperatures. Its only performance drawback is a high compressor discharge temperature when applied in low temperature refrigeration systems. As mentioned previously, it does have an ODP (0.055) and is being phased out. No new equipment containing HCFC-22 is being produced in the US, Europe and Japan. HCFC-123 replaced CFC-11 in low pressure centrifugal chiller applications. Chillers using this refrigerant have very good efficiency. Both the ODP and GWP of this refrigerant are quite low (0.02 and 77 respectively), but it is scheduled to be phased-out under the Montreal Protocol in the developed countries for new equipment in 2020. It is classified by ASHRAE as having higher toxicity (“B1”), but this has not been an issue in low emission equipment such as chillers which are typically located in machine rooms.

The most common HFCs in use are HFC-134a and the blended refrigerants R-410A, R-404A, and R-507. HFC-134a is currently being used for automotive air conditioning, in small refrigeration systems such as home refrigerators and vending machines, and in larger water chillers where screw and centrifugal compressors are employed. R-410A (a blend of HFC-32 and HFC-125) is used in many residential and small commercial air-conditioning systems as the replacement for HCFC-22. It operates at approximately 50% higher pressure, which dictates redesign of equipment, but this higher pressure does allow for more compact equipment to meet specified efficiency targets. In some equipment where redesign was not practical, a blend of HFC-32, HFC-125, and HFC-134a (designated R-407C) is used. This refrigerant operates at pressures that are similar to HCFC-22. The only drawback of this refrigerant is the higher temperature glide that can cause fractionation concerns and its somewhat lower efficiency relative to either HCFC-22 or R-410A. R-404A (R-125/143a/134a) and R-507 (R-125/143a) are used in commercial refrigeration systems such as supermarkets and replace R-502 (a CFC/ HCFC blend). Their low discharge temperature allows reliable operation of low temperature systems, however their efficiency is somewhat less than HCFC-22 in medium temperature refrigeration application and their GWP_{100} are fairly high (above 3900). Lower GWP HFC blends (e.g.R-407A) have been used mainly to retrofit and replace older HCFC-22 systems but have also been used in place of R-404A.

In an attempt to retain the desirable properties of the widely used HFC refrigerants, but with low GWP values, a new class of HFCs has recently been introduced. These incorporate a carbon-carbon double bond into the molecular structure; thus they belong to the chemical class of “olefins” and these new refrigerants are termed HFOs, for “hydrofluoroolefin.” The double bond provides a mechanism for rapid degradation in the atmosphere, leading to low GWP values. As of early 2011, two such HFOs (HFO-1234yf with a GWP_{100} of 4 and HFO-1234ze (E) with a GWP_{100} of 6) have been publicly disclosed; additional HFOs are under development. These two fluids have low toxicity and very low flammability (ASHRAE classification A2L). HFO 1234yf is offered as a low-GWP option for automotive air-conditioning applications, and has been approved for this use in the US. The HFOs are being actively investigated for many other applications, but much research remains to determine their application suitability.

Fluorocarbons and fluoroolefins are specially made for the application in air conditioning and refrigeration systems. The embedded energy required to manufacture these materials are typically about a carbon equivalent of 9 kg CO_2 eq per kg[17].

Lower-GWP Options

There is no generally accepted definition for what constitutes a “low-GWP” refrigerant. A regulatory inferred definition comes from the MAC directive of the European Union, which stipulates that only refrigerants with a direct global warming potential of 150 or lower (relative to CO_2 on a 100-year time horizon) may be used in automotive air-conditioning systems. This is an arbitrary value that was chosen to allow the use of HFC-152a but this is not based on a rigorous analysis nor does it denote an environmentally benign refrigerant. It should be noted that this limit was set only for auto air-conditioning applications, which are generally more leak prone than many other applications.

The UNEP Technical Options Committee for Refrigeration, Air-conditioning, and Heat Pumps [18] proposed seven groups based on the refrigerants GWP* and defines low-GWP as less than 300. These GWP groups, although proposed in 2010, have not been adopted by others. The difficulty arises from the fact that based on the current refrigerants in use each application has a different baseline and what constitutes '"low-GWP" is often referenced to the refrigerant that has traditionally been used in that application. It should be noted that the proposed amendment to the Montreal Protocol by the U.S., Canada, and Mexico does not set GWP limits but instead would introduce a GWP-weighted phase-down of all HFCs. This would allow flexibility for multiple GWP options as long as a country remains below its reduction target.

The refrigerants currently being evaluated to replace the higher-GWP HFCs all have drawbacks. HFC-32 has a GWP_{100} value of 675, and, like HFO-1234yf and HFO-1234ze (E), has an ASHRAE classification of A2L, which means that it is mildly flammable. Of the refrigerants with a GWP_{100} value less than 150, HFC-152a and the hydrocarbons are flammable. Ammonia is toxic. CO_2 operates at very high pressures and, often, in a trans-critical cycle (with generally lower efficiency).

In addition to the HFOs used as single-component refrigerants, blends of HFOs with conventional HFCs are being investigated. Such blends are tailored to match, as closely as possible, the characteristics of current refrigerants and thus meet the requirements of various applications. These blends have GWP_{100} values higher than the HFOs but lower than the HFCs they are intended to replace.

As pointed out earlier in this report, GWP should not be used as the sole criterion of environmental acceptability. If a lower GWP refrigerant is less efficient than the fluid which it replaces, any direct global warming benefit maybe offset by increased energy consumption. It is also clear that in order to meet the range of HVAC&R applications, a variety of refrigerants are required.

Mitigation of Risk

Risks of all types can be lessened by reduction of total system charge. Smaller charges can reduce the safety risks of a flammable refrigerant (a gas will not ignite in air below a finite concentration known as the "lower flammability limit" or LFL), and may allow the use of such refrigerants in many more applications. Reduction of charge would reduce the environmental consequences of refrigerant release due to leaks, accident, or improper disposal.

Ideally, refrigerants should not be emitted from equipment during normal operation. In practice, refrigerant losses are a function of system size, design, installation, and maintenance of the equipment. In general, small factory-sealed systems such as refrigerators can operate to the end-of-life without loss of refrigerant charge. Automotive air-conditioning systems may require recharging due to losses through hoses. Larger field-erected systems, such as those used in supermarkets, are more vulnerable to refrigerant losses due to the magnitude of components and piping required to meet their refrigeration loads. Proper design, fabrication, installation, maintenance and disposal procedures can greatly reduce the emissions and environmental impact of refrigerants.

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*- The 2010 Assessment Report of the Technical Options Committee for Refrigeration, Air-conditioning, and Heat Pumps, published by UNEP, has proposed a classification scheme that distinguishes between very low (or ultra-low) with GWP ≤30,very low with GWP ≤100,low with GWP ≤300, moderate with GWP ≤1000, high with GWP ≤3,000,very high with GWP ≤10,000,and ultra-high with GWP ≤10,000.

To address these issues, ASHRAE has published Standard 147,*Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment*[8]. An example of a best practices guide is also available from the EPA[19].

One strategy for reducing both system charge and emissions that has been successfully applied in supermarkets is to locate the refrigeration equipment outside or in a machine room with heat exchange loops circulating a secondary coolant (e.g., CO_2 or a glycol/water solution) to the refrigerated display cases. This approach can also be applied to other systems, and requires good design practice to offset any energy penalty from the additional heat exchange loop [20].

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CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

January 27, 2017

ASHRAE Refrigeration Committee (REF)

Liaison Report to
Chapter Technology Transfer Committee

2017 Winter Conference, Las Vegas

REF Liaison: **Charles Hon**
chon@truemfg.com

1

CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

TOPICS

- **Refrigeration Update**
- **Chapter Program Support**
- **Advance Chapter Interest in Refrigeration**

2

CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

- Refrigeration Program for Las Vegas

- The 2017 ASHRAE Winter Conference will have a Workshop (Workshop 2 Sunday 8:00 to 9:00 am) "Optimization of Direct AC Systems with Low GWP Refrigerants"

  - Study on Properties of Low GWP Refrigerants (Osami Kataoka)
  - Analysis of Test Results on Low GWP Refrigerants (Reinhard Radermacher)

3

CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

- Refrigeration Program for Las Vegas
- "Food Cold Chain for Developing Countries" (Workshop 6 Monday 9:45 to 10:45 am)
- International Policy to Build a Sustainable Cold Chain in Developing Countries (Didier Coulomb)
  - Refrigeration Industries Projects in Developing Countries (Jon Shaw)

4

CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

- Refrigeration Program for Las Vegas Research Update:
- Activities Toward the Safe Use of Low GWP Flammable Refrigerants (Wednesday 8:00 to 9:30 am)

1. AHRTI Research Projects on Flammable Refrigerants (Xudong Wang)
2. ASHRAE Research Projects on Flammable Refrigerants (Kenneth Schultz)
3. ORNL Research Effort on Charge Limits for Various Types of Equipment Employing Flammable Refrigerants (Omar Abdelaziz)
4. NIST Effort on Modeling Tools for Flammability Ranking of Low GWP Refrigerant Blends (Gregory Linteris)

5

CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

- Refrigeration Program for Las Vegas Seminar 72
- Introducing the Guide for Sustainable Refrigerated Facilities and Refrigeration Systems (1634 –RP) (Wednesday 11:00 am to 12:30 pm)

1. Refrigeration Systems for Refrigerated Facilities: The Current Landscape (Douglas Reindl)
2. Overview of ASHRAE Design Guide for Refrigerated Facilities (Richard Love)
3. Applying the ASHRAE Design Guide for Refrigerated Facilities (Todd Jekel)

6

CTTC REF Report
<u>ASHRAE Winter Conference – Las Vegas 2017</u>

- **REF Review of Position Documents**

  “Ammonia as a Refrigerant” has been approved by REF and should be approved by the Tech Council in Las Vegas

  “ASHRAE Position Document on Refrigerants and their Responsible Use” (under review)

  Expires July 2, 2017

7

CTTC REF Report
<u>ASHRAE Winter Conference – Las Vegas 2017</u>

- **REF Webpage with Links**
  - **Members First! Tech Council Newsletter**
- **REF Operations**
  - **Recent Meeting Minutes**
  - **Manual of Procedures, Rules of the Board, REF Reference Manual**
  - **Members First! Newsletters**
  - **REF Liaison Report to CTTC**

8

CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

- REF Webpage with Links
  - REF Resources/Chapter Program Support
    - To Support Chapters, REF has Developed Refrigeration-themed Program Materials
      - "Tips on Hosting Successful Refrigeration-focused ASHRAE Chapter Meeting"
      - ASHRAE Distinguished Lecturers (DL) list (edited to include only Refrigeration Topics)
      - ASHRAE Refrigeration Speakers list (expanded for improved geographic coverage in developing countries)
      - Sister Refrigeration Organizations

9

CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

- REF Webpage
  - Refrigeration Technology Awards by REF
    - Recognize the Designer and Owner of the Refrigeration Project exhibiting the Best Innovation and/or New Technology with Links to:
      - "Milton W. Garland Commemorative Refrigeration Award for Project Excellence"
      - "Refrigeration Comfort Cooling Award for Project Excellence"
      - Awarded at Plenary Session during Annual Conference

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CTTC REF Report
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- **REF Webpage**
  - **Member Resources**
    - **REF Assists Technical Committees (TCs) with Refrigeration Oriented Goals and Provides links to:**
      - **Refrigeration TC Webpages**
      - **Refrigeration TC Activity Report**
      - **Refrigeration-related ASHRAE Research**
      - **Refrigeration-related Standards and Guidelines**

11

CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

- **Chapter Program Support – Efforts Underway**
  - **Encourage Expert Refrigeration Speakers for DL Program**
  - **Encourage Refrigeration Programs with broad appeal to Chapters**
  - **Develop list of Refrigeration Programs and Speakers with wide appeal**

12

CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

- **Advance Chapter Interest in Refrigeration**
  - **REF seeks to promote Refrigeration Education and Training for Students and Seasoned Practitioners**
    - **Technology Transfer Programs**
      - **Refrigeration Programs at ASHRAE Conferences**
      - **"George C. Briley ASHRAE Journal Award"**
        - **Best Refrigeration-related Article**
        - **Awarded at REF Meeting, Winter Conference**

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CTTC REF Report
ASHRAE Winter Conference – Las Vegas 2017

- **Advance Chapter Interest in Refrigeration**
  - **REF continues to work with and thru CTTC to Identify and Develop Resources and Implement Programs to enhance Chapter Refrigeration Activities including:**
    - **Work with the TCs to develop Hands-on, Low Cost Refrigeration Projects for College Lab Classes**
    - **Present Seminars at ASHRAE Conferences on Refrigeration Topics**
    - **Promote and solicit applications for Milt Garland, Comfort Cooling, and George Briley Refrigeration Awards**
    - **Submit recommendations to CTTC for PAOE criteria for Chapter Refrigeration Activities**
    - **Strongly encourage RVCs to actively promote strong Chapter participation in the recently approved "R in ASHRAE" Award**

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CTTC REF Report

ASHRAE Winter Conference – Las Vegas 2017

THANK YOU

For your Participation & Support of ASHRAE Activities

15

January 29, 2017

Regulatory Update

KARIM AMRANE – CHAIR, REFRIGERATION COMMITTEE

Montreal Protocol Developments

- Agreement on HFC phase down reached in Kigali, Rwanda
  - Reduces greenhouse gas emissions by 70 Gigatons CO_2e by 2050
  - Separate baselines and reduction schedules for A2 and A5 countries
  - Will be guided by a technology and economic review process every 5 years
  - Provides financial assistance to developing countries
  - Will go into effect in 2019
  - Needs ratification by U.S. Senate

Phase Down Schedule

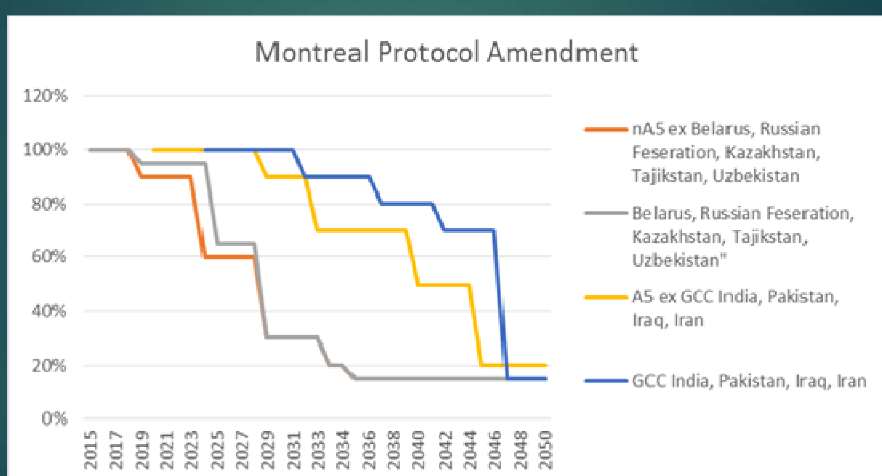
	A5 Group 1	*A5 Group 2*	**A2**
Baseline	2020-2022	2024-2026	2011-2013
Formula	Average HFC consumption	Average HFC consumption	Average HFC consumption
HCFC	65% baseline	65% baseline	15% baseline*
Freeze	2024	2028	-
1st step	2029 – 10%	2032 – 10%	2019 – 10%
2nd step	2035 – 30%	2037 – 20%	2024 – 40%
3rd step	2040 – 50%	2042 – 30%	2029 – 70%
4th step			2034 – 80%
Plateau	2045 – 80%	2047 – 85%	2036 – 85%

* For Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan 25% HCFC component of baseline and different initial two steps (1) 5% reduction in 2020 and (2) 35% reduction in 2025

Notes:

1. Group 1: Article 5 parties not part of Group 2
2. Group 2: GCC, India, Iran, Iraq, Pakistan
3. Technology review in 2022 and every 5 years
4. Technology review 4-5 years before 2028 to consider the compliance deferral of 2 years from the freeze of 2028 of Article 5 Group 2 to address growth in relevant sectors above certain threshold.

HFC Phase Down Agreement – Montreal Protocol



EPA Regulations

- SNAP de-listing of High GWP refrigerants
  - Commercial Refrigeration (July 2015)
  - Chillers, cold storage warehouses (September 2016)
- Refrigerant management - Extension of section 608 to HFCs (September 2016)
- Next steps
  - Unclear given change of administration
    - Montreal Protocol, SNAP

Regulatory Outlook - California Short-Lived Climate Reduction Strategy

- Proposed to reduce HFC emissions by 40% by 2030
  - First published in April 2016
  - Revised in November 28, 2016
- Revised strategy:
  - Includes incentive programs to defray cost of low-GWP
  - Stresses importance of energy efficiency for low-GWP refrigerants
  - Proposes ban on sale of high GWP refrigerants ≥ 2,500 and

Stationary Refrigeration or Stationary Air-Conditioning Sector	Refrigerants Prohibited in New Equipment with a 100-year GWP Value:	Proposed Start Date
Non-residential refrigeration	150 or greater	CARB to further evaluate
Air-conditioning (non-residential and residential)	750 or greater	CARB to further evaluate

- California-specific HFC phasedown not necessary
  - Comments due on January 17, 2017
  - Board hearing on March 23-24 2017
- Regulation expected to start in 2017

Regulatory Outlook - Environment & Climate Change Canada (ECCC)

- Proposed regulations issued on November 26, 2016
  - Regulatory measures on HFCs – Objective harmonize with the U.S. SNAP (similar to March 2016 proposal)

Application	GWP Limit and Effective Date
Ref – Stand alone MT	Max 700 GWP; Jan 1, 2020
Ref – Stand alone LT	Max 1500 GWP; Jan 1, 2020
Ref – Central systems >20 kW (racks, both MT/LT)	Max 1500 GWP; Jan 1, 2020
Condensing unit - Refrigeration systems ≤20 kW (both MT/LT)	Max 2200 GWP; Jan 1, 2020
Foams	Max 150 GWP; Jan 1, 2021
AC – Chillers	Max 700 GWP; Jan 1, 2025

- Phase-down (North American Proposal) also proposed (2019-90%; 2024-65%; 2030-30%; 2036-15%; baseline 2011-2013)
  - Canadian Gazette part II will have phasedown schedule consistent with Montreal Protocol agreement
- Comments due on February 8, 2017

http://www.gazette.gc.ca/rp-pr/p1/2016/2016-11-26/html/reg1-eng.php

Safety Codes and Standards

- ASHRAE 15 proposed requirements for 2L refrigerants - Completion by end of 2017
  - Addendum d addresses "high-probability systems" in applications for human comfort
  - Addendum h, addresses machinery room applications
- ASHRAE 15.2
  - Addresses residential applications - Completion by end of 2017
- IMC
  - 2018 code cycle over – Does not address 2L refrigerants
- IFC
  - 2018 cycle underway – One proposal amending requirements on machinery room ventilation approved
- UMC
  - 2018 cycle underway – Task force established to develop requirements on 2L refrigerants
- IEC 60335-2-40
  - Revisions underway to include 2L refrigerants – Completion by end of 2017
- IEC 60335-2-89
  - Revisions underway to increase minimum charge limit for A3 refrigerants – Completion by end of 2017

Execution Plan

AHRTI, ASHRAE and DOE Joint Research Effort on Flammable Refrigerants

Latest Update date 10/7/2016

Coordinated activities timeline (timeline is estimated and projects should start as early as possible.)

Responsible Org.
AHRI
ASHRAE
DOE

	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18
IMC IRC 2021	change proposals for IMC and IRC 2021 are due in January 2018																				
ASHRAE 15 and 15.2	finalized draft standards published for PPR														addressing comments and publishing standards						
AHRTI Project No. 9007 Benchmarking Risk by Real Life Leaks and Ignitions Testing		project completes within 9 months (project started)																			
ASHRAE-1806: Flammable Refrigerants Post-ignition Risk Assessment								project completes within 12 months (interim results feed to relevant standard committees as needed) (RFP issued on 10/6/2016, proposals due on 11/14/2016)													
ASHRAE-1807: Guidelines for flammable refrigerant handling, transporting, storing and equipment servicing and installation										project completes in 6 months (The WS is pending the MTG approval. It will be reviewed by RAC)											
ASHRAE-1808: Servicing and Installing Equipment Using Flammable Refrigerants: Assessment of Field-made Mechanical Joints										project completes in 6 months (The WS is pending the MTG approval. It will be reviewed by RAC)											
AHRTI Project No. 9009 Leak Detection of A2L Refrigerants in HVACR Equipment					project completes in 6 months (project started)																

	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18
IMC 2021	change proposals for IMC 2021 are due in January 2018																				
UL 60335-2-40	a final draft for preliminary comments from WG10							addressing comments and publishing standards													
Determination of setting charge limits for various types of equipment employing flammable refrigerants				Phase I (review and seek stakeholders input) completes in 4 months (workshop on 10/24/2016)																	
								Phase II (CFD study) completes in 9 months													
AHRTI Project No. 9008 Investigation of Ignition Temperature (Hot surface and Auto Ignition) for 2L Refrigerants				project completes in 6 months (project started)																	

Note: The DOE funded long term project at National Institute of Standards and Technology is not listed in this page. The project title is Modeling Tools for Flammability Ranking of Low-GWP Refrigerant Blends.

Questions & Discussion

Refrigeration Committee
Karim Amrane, Chair
Date:1/29/2017

Item #	MBO	Status	Date Due	Assigned To	Applicable Strategy #	MBO Comments	UPDATE
Included in Definition of Roles							
1	Develop and Expand Refrigeration Education & Outreach	OPEN	1/31/2017	Royal, Shockley, Rule	1c, 3d	i) Broadcast information on Milton Garland comfort cooling & Briley Awards in ASHRAE Insights and Members Newsletter. ii) Organize ALI Subcommittee. Assist in the development of programs for regional chapters on refrigeration concepts. Liaise with YEA. Royal developing course proposal with ALI. iii) Continue to support Handbook Subcommittee to assist with Refrigeration Handbook chapters. Shockley working with Don Fenton. iv) Update position document on ammonia v) revise Refrigerants and their Responsible Use PD	Awards will be publicized in Insights, on website , Members 1st newsletters. Handbook chapter reviews ongoing with reviewers found through GCCA and ASHRAE CoF. REF exploring ALI course for Long Beach. PD on ammonia revision approved and sent to Tech Council. Requested reaffrimation of current Refrigerants PD with request to revise
2	Support of ASHRAE Developing Economy Objectives	OPEN	1/31/2017	Dieryckx, Minor, Coulomb	4a, 4b, 3b	i) Training on environmental and safety concerns of alternative refrigerants for developing countries ii) Develop guidance on available alternatives or resources which promote energy efficient alternatives iii) Support dissemination of GRMI principles to developing countries	REF exploring deliverables requested from Ad Hoc report. Programs relevant to developing economies planned for Las Vegas. ASHRAE is on GRMI steering committee.
3	Implementation of UNEP Partnership Goals	OPEN	Ongoing	Nair-Bedouelle, Aguilo, Robbins	4a, 4b	i) ASHRAE & UNEP will explore opportunities to promote responsible and sound management of refrigerants ii) ASHRAE and UNEP to cooperate and coordinate efforts related to energy efficiency in the buildings sector iii) ASHRAE through its Distinguished Lecturer (DL) program will work with UNEP to provide speakers to collaborative activities between UNEP and ASHRAE chapters/sections	Joint ASHRAE, UNEP, IIR conference on sustainable management of refrigeration technologies in mobile marine and fisheries sectors (Bangkok 2017). Linked to MBO#2 deliverables Refrigerants awareness package low GWP program (launching tomorrow)
4	Serve as the Technical Experts for Refrigeration related issues for ASHRAE	OPEN	Ongoing	Hon, Rajendran, Dieryckx, Minor	3c, 4a	i) Provide technical input to Tech Council and/or ASHRAE staff on refrigeration related legislative and regulatory issues ii) Act as a technical resource to RAC and the MTG on Lower GWP refrigerants on the ASHRAE research effort addressing flammable refrigerants	Ongoing. REF subcommittee to review current process for this to happen and how effective process can be installed.
5	Effective communication and operation of the REF Committee	OPEN	Ongoing	Amrane, Shockley, past Chairs	2a, 2b, 2c	i) Assure Technical Committee alignment ii) Development of a Planning Subcommittee for REF (current and future leadership) iii) Continued collaboration with other REF related organizations	REF established subcommittee structure to help coordinate liaison activities and assignments. Liaisons with IIR, IIAR, GCCA, UNEP assigned. Liaising with ASHRAE TCs, SSPCs as well

MBO #2 – Support of ASHRAE Developing Economy Objectives

Didier Coulomb
Martin Dieryckx
Barbara Minor

January 29, 2017

ASHRAE Refrigeration Committee

ASHRAE Technical Program – Jan, 2017

Sunday

8:00 AM - 9:00 AM
Workshop 2

Optimization of Direct AC Systems with Low GWP Refrigerants
Track: Fundamentals and Applications

Sponsor: Refrigeration Committee
Chair: Martin Dieryckx, Daikin Europe NV, oostende, Belgium
In view of the requirement to reduce the climate impact of refrigerants, several refrigerants are proposed for use in direct expansions air-conditioning systems. There are test programs such as AREP and PRAHA to evaluate some of the solutions. The results of these tests do not always give the straight answer that we expect. How should we read these results and what parameters are most important to decide the refrigerant for the specific application. This workshop has the target to give a better insight how the next generation refrigerant can be decided for direct expansion AC equipment.

1. Study on Properties of Low GWP Refrigerants
Osami Kataoka, Member, Daikin Industries, Ltd., Osaka, Japan
2. Analysis of Test Results on Low GWP Refrigerants
Reinhard Radermacher, Ph.D., Fellow ASHRAE, University of Maryland, College Park, MD

Monday

9:45 AM - 10:45 AM
Workshop 6

Food Cold Chain for Developing Countries
Track: Fundamentals and Applications

Sponsor: Refrigeration Committee
Chair: Didier J. Coulomb, Dr.Ing., IIR, Paris, France
Developing countries have lower refrigeration capacities than developed countries and thus more post-harvest losses. International organizations and private companies need to invest in these countries.

1. International Policy to Build a Sustainable Cold Chain in Developing Countries
Didier J. Coulomb, Dr.Ing., Member, IIR, Paris, France
2. Refrigeration Industries Projects in Developing Countries
Jon Shaw, CEng, Member, Carrier, Washington, DC

Other Programs in Vegas

UNEP UNIDO AHRI U.S. DEPARTMENT OF ENERGY

You're invited!

The United Nations Environment Programme (UNEP), United Nations Industrial Development Organization (UNIDO), AHRI, and the U.S. Department of Energy invite you to a joint seminar entitled:

Lower-GWP Alternatives for High Ambient Conditions: Are We Ready?

Tuesday, January 31, 2017, Las Vegas Convention Center- Room N238/240 (1-3 p.m.)

Click here to view the Seminar Abstract and Program.

Attendance is open to interested participants and to all 2017 AHR Expo registrants.

We look forward to seeing you at the seminar!

ASHRAE not involved in planning

Other Programs in Vegas

SUSTAINABLE TECHNOLOGIES FOR STATIONARY AIR CONDITIONING WORKSHOP
LAS VEGAS CONVENTION CENTER
LAS VEGAS, NEVADA, USA
Wednesday, 1 February 2017

DRAFT AGENDA

TIME	AGENDA TOPIC	SPEAKER/AFFILIATION
08:00	Registration of participants	
	Opening Session	
08:30 to 08:40	Welcome	TBD
	Introduction of sessions and organization of work	TBD
	Session I: Overview and General Aspects of Air Conditioning **Format: presentations followed by Q & A**	
08:40 to 10:00 (80 mins)	Fields of Application for Stationary Air Conditioning	Steve Yurek, AHRI
	Not-in-kind alternatives (Evaporative cooling and façade greening)	Marco Schmidt, German Federal Office for Building and Regional Planning
	Energy Efficiency	Walid Chakroun, ASHRAE/Kuwait University
	Energy Efficiency – European perspective and developments	Andrea Voigt, EPEE
	Discussion/Q&A	All participants
10:00-10:15	**Tea/Coffee Break**	
	Session II A: Low GWP Alternatives for Residential and Light Commercial Applications **Format: 5 panelists with a moderator**	
	Alternatives for unitary AC including window, portable, central ducted, split, rooftop and packaged terminal air conditioning, to include discussion on topics such as energy efficiency, standards and safety issues, and performance under high ambient temperature conditions.	
	Moderator: Cindy Newberg, U.S. EPA	

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ORGANIZERS
Climate and Clean Air Coalition
Governments of Canada, Germany, USA
Alliance for Responsible Atmospheric Policy

ASHRAE not involved in planning

MBO #2 - Relevance to Strategic Plan – status/output of projects?

Initiative 3B	Owner/Operator Focus Groups
Description	Collect ASHRAE member demographics on owners/operators around the world. Conduct three focus groups to understand owner/operator opportunities (one outside the U.S.). Three groups at 7 per group plus facilitators (volunteer led with staff support). Based on the results on the focus groups, develop products and services such as use Standard 180 as the foundation of a fundamentals of a high performing building operations and maintenance training course. Explore co-branding with BOMA or IFMA at zero development cost to them provided they provide marketing support and committee volunteers.
Timeframe	2014–15 Society Year
Cost	$25,000 during 2014–15 for travel, facilities. $90,000 for course development.
Staff	Steve Comstock
Revenue/Upside	Education course revenue. Membership growth.
Responsible Party	Members Council/Pub & Ed Council

Table 4: Initiative 4

Initiative 4A	Global membership assessment and development of Global Strategy
Description	Conduct detailed survey of members outside North America to understand how ASHRAE can serve them more effectively. Prepare a Global Strategic Plan for BOD on how to effectively and quickly establish ASHRAE's role in the global community.
Timeframe	2014–15 Society Year
Cost	$15,000 for consultant to audit questions; survey conducted directly by ASHRAE
Staff	Joyce Abrams
Revenue/Upside	Contributes to long-term membership growth.
Responsible Party	Planning Committee

Initiative 4B	Global Study with a consultant to evaluate ASHRAE's opportunities
Description	Work with a consultant such as MCI to ascertain what ASHRAE's opportunities are globally and develop some business models to achieve the goals. This material will be included in the Global Strategic Plan development in Initiative 4A.
Timeframe	2014–15 Society Year
Cost	$100,000
Staff	Steve Comstock
Revenue/Upside	Contributes to long-term membership growth and strengthens the exposure and role of ASHRAE in the global community.
Responsible Party	Planning Committee

Path Forward

- Potential future ASHRAE Workshop
  - Safety Considerations for AC and Refrigeration Equipment in Developing Economies
- Continuation of this MBO? – Didier comments
  - ASHRAE wants to be more present in developing countries, but no precise objective has been defined
  - Current ASHRAE activities in developing countries are essentially joint actions with other organizations including UNEP and IIR
  - This may be the best way to proceed moving forward
  - For discussion