Deconstructing Flammable Refrigerants:

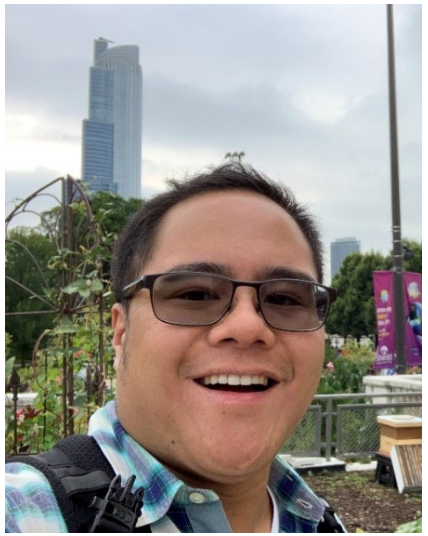
The Who, What, Why, and How of Flammable Refrigerants

May 3, 2022

Call-in Details 1-202-991-0477 ID: 850 473 130#

Today's Host

Kersey Manliclic, Doctor of Philosophy (PhD)
U.S. Environmental Protection Agency
Stratospheric Protection Division
GreenChill Partnership
Phone: (202) 566-9981
Email: manliclic.kersey@epa.gov

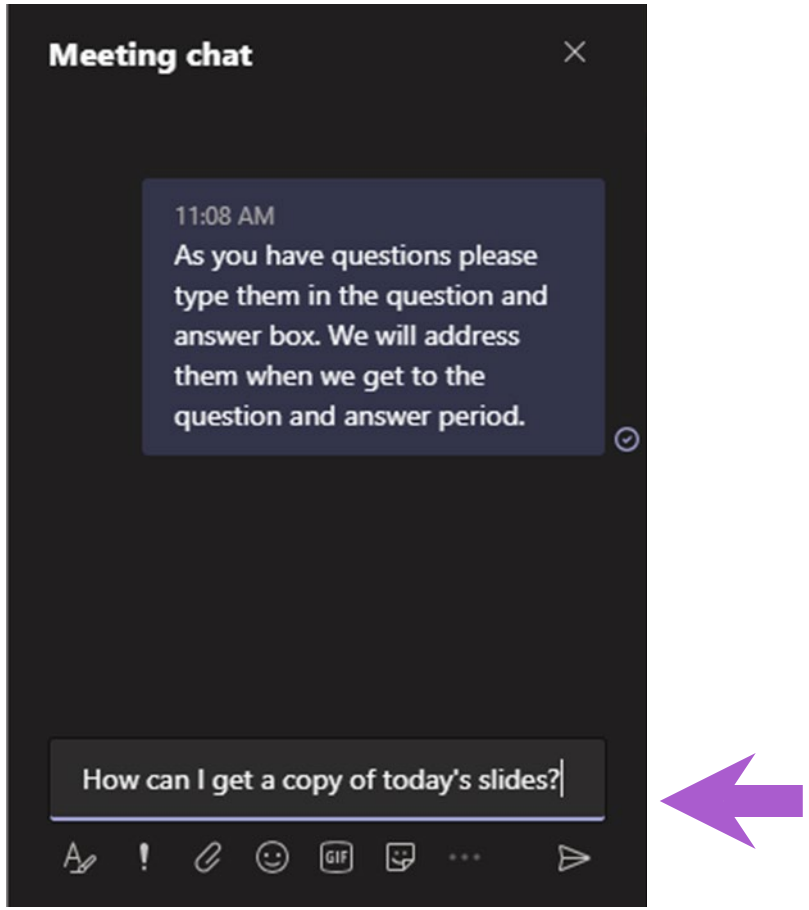


Kersey has worked in various sectors before coming to the U.S. Environmental Protection Agency (EPA). Most recently, he worked for 3.5 years at the California Air Resources Board implementing an incentive program for cleaner agricultural equipment and ensuring that Cap-and-Trade incentive programs benefitted disadvantaged communities. Prior to that, he worked with state agencies to plan hydrogen fueling infrastructure for fuel cell electric vehicles. He holds a Bachelor of Science (BS) in Mechanical Engineering, a BS in Materials Science & Engineering, a Masters of Science (MS), and a PhD in Environmental Engineering, all from the University of California, Irvine.

Questions and Webinar Feedback

Question and Answer Session

- Participants are muted
- Questions will be moderated at the end
- To ask a question, enter your comment into the chat box



Feedback Form

- We value your input!
- The link to a feedback form will appear in the chat window

Call-in Details 1-202-991-0477 ID: 850 473 130#

Webinar Materials

Recording and Slides

- Webinar is being recorded
- Materials will be posted on the GreenChill website under Events and Webinars: www.epa.gov/greenchill
- To receive notification when materials are posted email: EPA-GreenChill@abtassoc.com

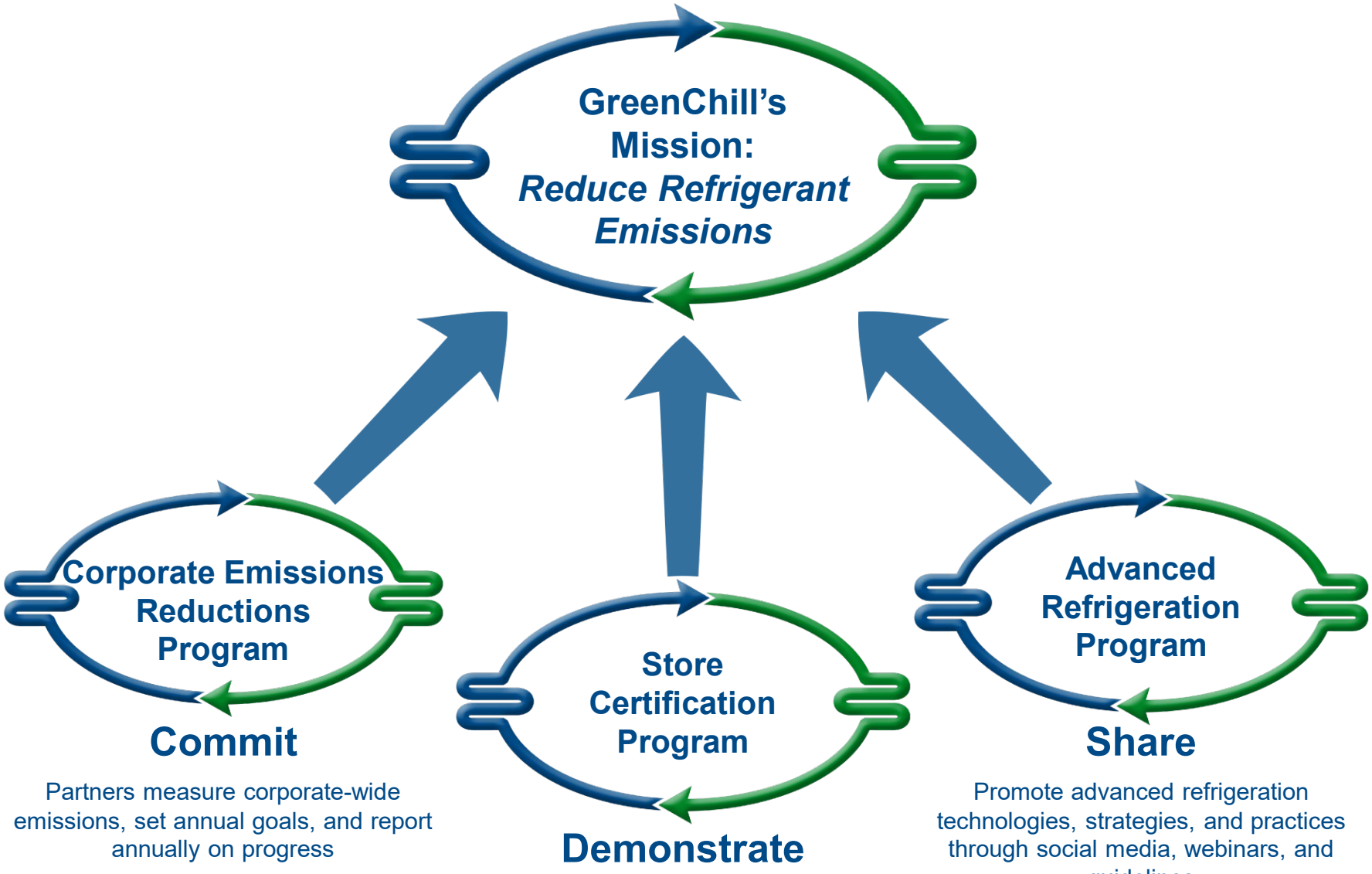
Program Overview

www.epa.gov/greenchill

GreenChill is a voluntary partnership program that works collaboratively with the food retail industry to reduce refrigerant emission and decrease stores' impact on the ozone layer and climate system

GreenChill works to help food retailers:

- Lower refrigerant charge sizes and eliminate leaks
- Transition to environmentally friendlier refrigerants
- Adopt green refrigeration technologies and best environmental practices


GreenChill's Mission: *Reduce Refrigerant Emissions*
Corporate Emissions Reductions Program
Commit
Partners measure corporate-wide emissions, set annual goals, and report annually on progress
Store Certification Program
Demonstrate
Individual stores earn GreenChill certification for meeting highest standards: low charge size, use of less harmful refrigerants, and low leak rates
Advanced Refrigeration Program
Share
Promote advanced refrigeration technologies, strategies, and practices through social media, webinars, and guidelines

Upcoming GreenChill Webinars

- **June 15: Refrigerant Banking**
  - Presenters from National Refrigerants will discuss refrigerant banking.
- **June 21: Solutions to Meeting Food Retailer Equipment Specifications**
  - Presenters from the North American Sustainable Refrigeration Council will present on food retail refrigeration leaks: exploring the true cost and equipment specification solutions.
- All GreenChill webinars are at 2-3 PM Eastern
- To be added to our webinar invitation list, email EPA-GreenChill@abtassoc.com

Celebrating 15 Years of GreenChill

2022 is the 15th anniversary of GreenChill!

- 15th anniversary report later this year
- Explore GreenChill's Partner accomplishment page
- Email greenchill@epa.gov if you have ideas on how to celebrate!

www.epa.gov/greenchill/partnership-accomplishments

Learn More

www.epa.gov/greenchill

GreenChill@epa.gov

Today's Speakers…

Chuck Allgood, PhD

Chuck Allgood, PhD
Chemours
Technology Fellow
charles.c.allgood-1@chemours.com

Chuck has over 30 years in the heating, ventilation, air conditioning, and refrigeration (HVACR) industry, having held a variety of research, development, business, and technical service positions with Chemours. He holds a PhD in Chemistry and prior to joining DuPont worked for the National Institute of Standards and Technology. A frequent speaker at many industry events, Chuck currently leads the technical service, training, and applications development activities for the Freon™ and Opteon™ brand refrigerants.

Andrew Pansulla

Andrew Pansulla
Chemours
Global Technical Service Engineer
andrew.r.pansulla@chemours.com

Andrew is the global technical service engineer for Chemours Refrigerants. He holds a Master's degree in Chemical Engineering from Lehigh University. Over the past seven years with Chemours & DuPont he has primarily been focused on the development of next generation refrigerants for the HVACR industry. His assignments have included the quantification of performance for next generation Hydrofluro-Olefin (HFO) refrigerants in controlled laboratory settings and working in the field with end users to optimize their refrigeration systems.

Mitch Newsome

Mitch Newsome
Chemours
Market Development Consultant
mitch.newsome@chemours.com

Mitch graduated from the University of South Carolina in 2014 with a bachelors in Finance. Mitch has spent the last five years working for mechanical contractors in roles focused on new business development. In his last role at CoolSys Commercial and Industrial, Inc he worked on building relationships with supermarket end-users seeking to retrofit aging infrastructure and inadequate systems. In 2021, Mitch completed the construction leadership program (ICML) at the University of Colorado Denver further adding to his insights on the operating challenges end users are facing today. Mitch joined Chemours in September of 2021 as market development consultant for retail refrigeration where he will work with end users to identify optimum solutions to meet their current and future refrigerant needs.

Opteon™ Refrigerants

Chemours™

Deconstructing Flammable Refrigerants

The Who, What, Why, and How of Flammable Refrigerants

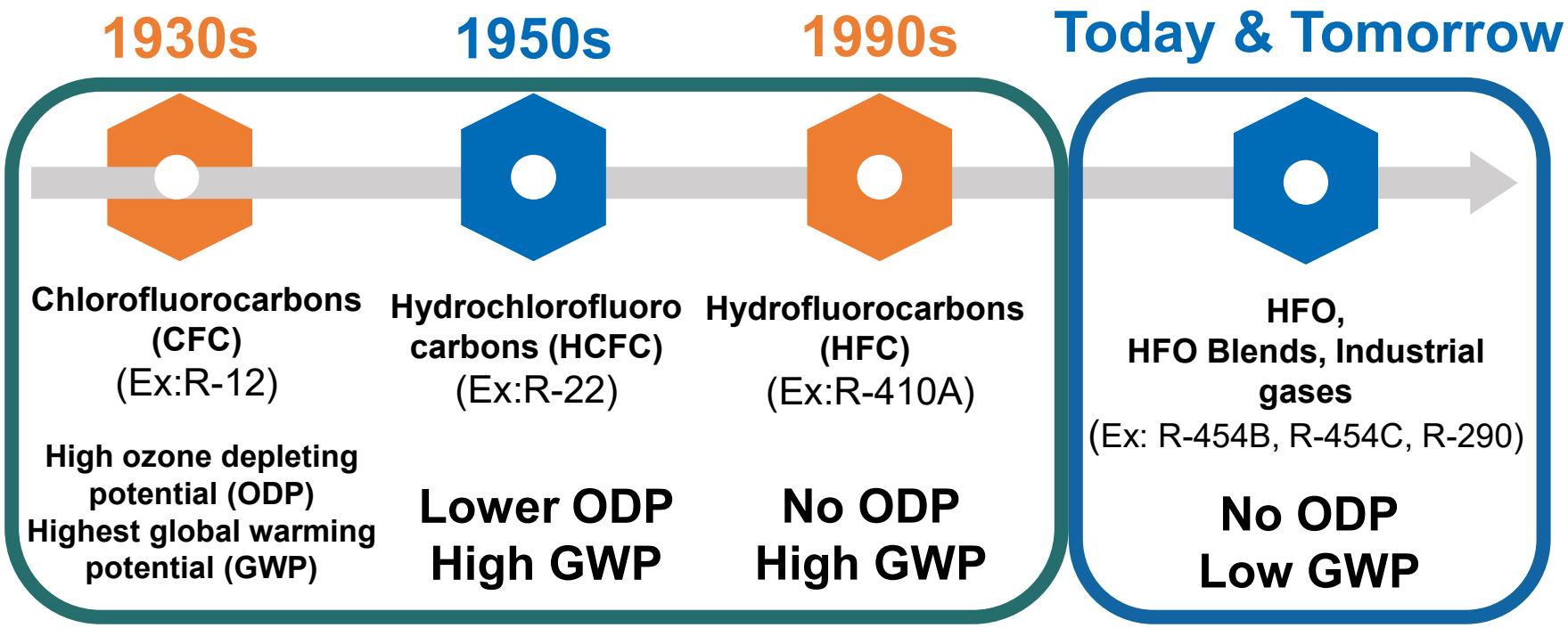
www.opteon.com

May 3, 2022

Agenda

- Refrigerant Flammability Basics
- Practical Comparisons – Flammability Class 1, 2L, and 3
- Application of A2Ls – Systems, Standards & Codes
- Total equivalent warming impact (TEWI) and Example of A2L Installation
- Summary
- Question and answer

Refrigerant History



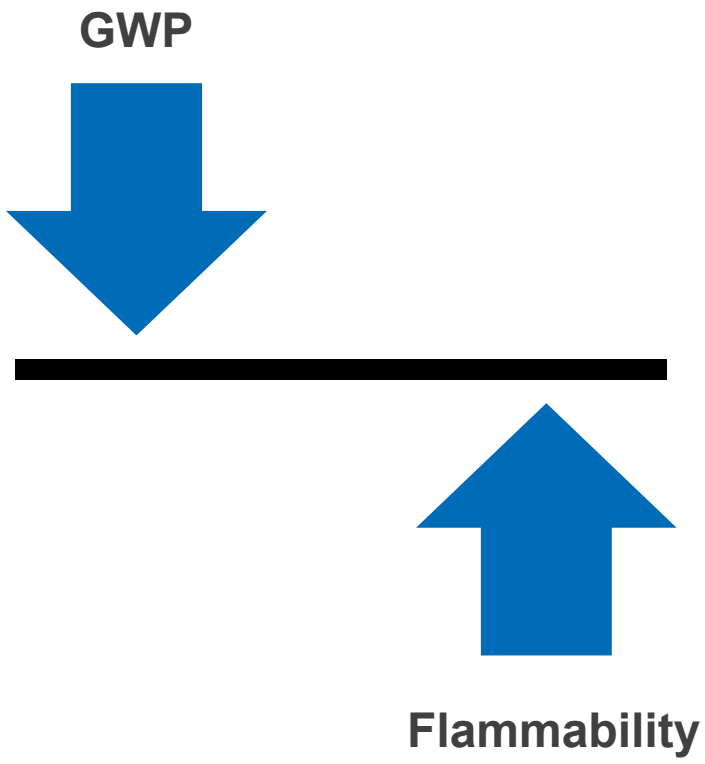
American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) 34
A1 Classification

ASHRAE 34
A2L Classification

ASHRAE Standard 34

Current:

R-404A = 3922 GWP (44% R-125 / 52% R-143a / 4% R-134a)



Lower GWP
Non-Flammable

Incumbent Gases
R-134a, R-22, R-404A

Increasing Flammability

Higher Flammability	A3	B3
Flammable	A2	B2
Lower Flammability	A2L	B2L
No Flame Propagation	A1	B1
	Lower Toxicity	Higher Toxicity

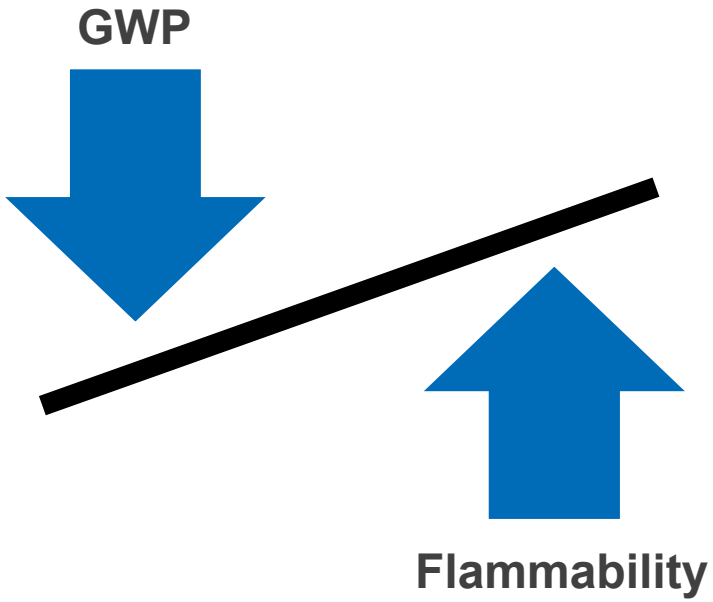
Increasing Toxicity

ASHRAE Standard 34

Lowering GWP results in increasing flammability properties

R-404A = 3922 GWP (44% R-125 / 52% R-143a / 4% R-134a)

R-454C = 148 GWP (21.5% R-32 / 78.5% R-1234yf)



R-454A, R-454B, R-454C, R-32, R-1234yf

Lower GWP Non-Flammable

Incumbent Gases R-410A, R-22, R-404A

Increasing Flammability

Higher Flammability	A3	B3
Flammable	A2	B2
Lower Flammability	A2L	B2L
No Flame Propagation	A1	B1
	Lower Toxicity	Higher Toxicity

Increasing Toxicity

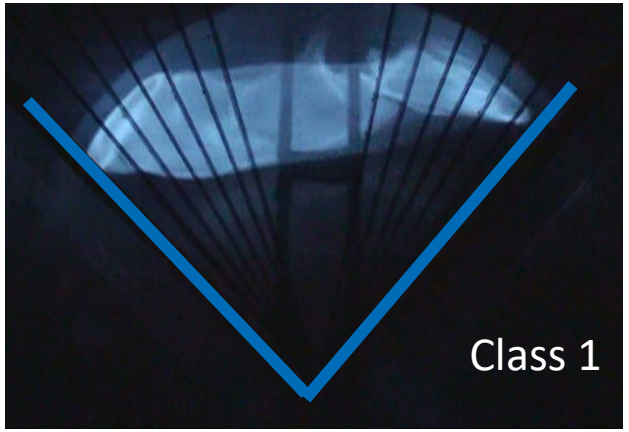
Opteon™ Refrigerants

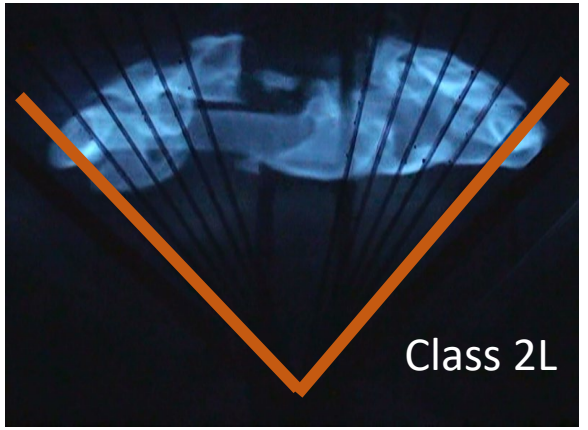
Chemours™

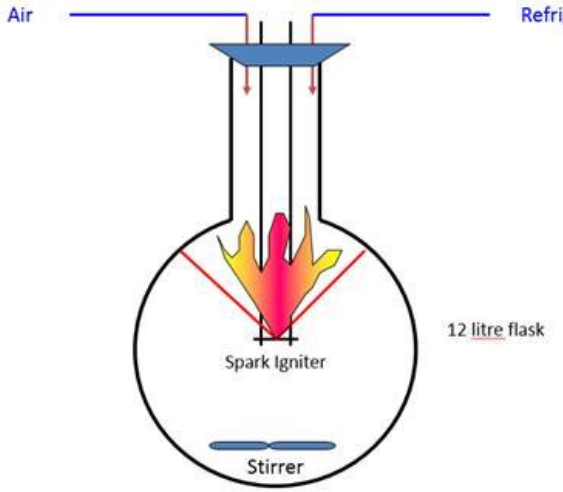
American National Standards Institute E681, E582, D3065 Industry Tests for Refrigerants

American Society for Testing and Materials (ASTM) E681 Test Examples

- Flame spread **< 90°** indicates "no flame propagation"
- Flame spread **> 90°** indicates "flammability"
- An A2L classification means the flame exceeded the **90°** parameter and the flame spread is slow

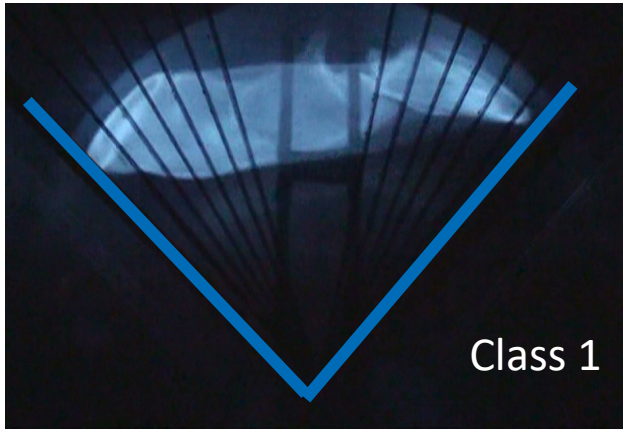


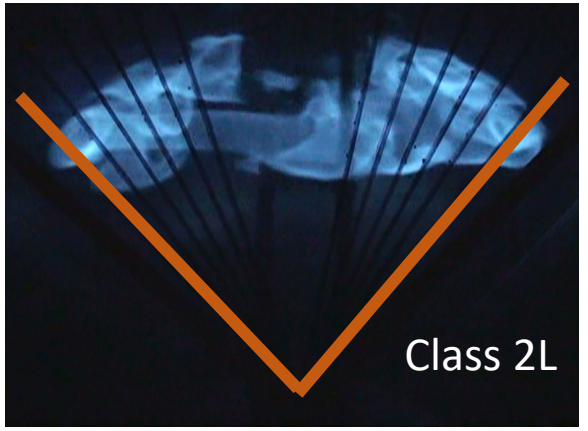


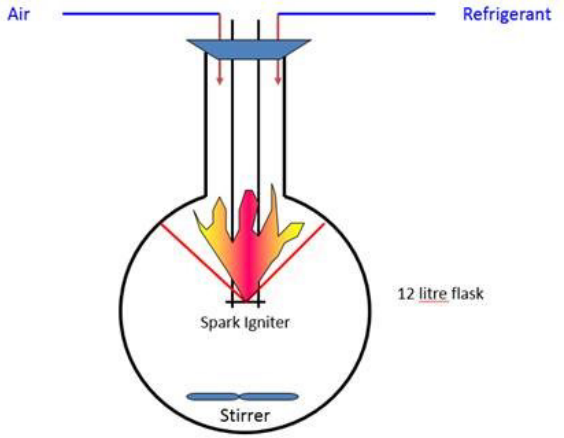


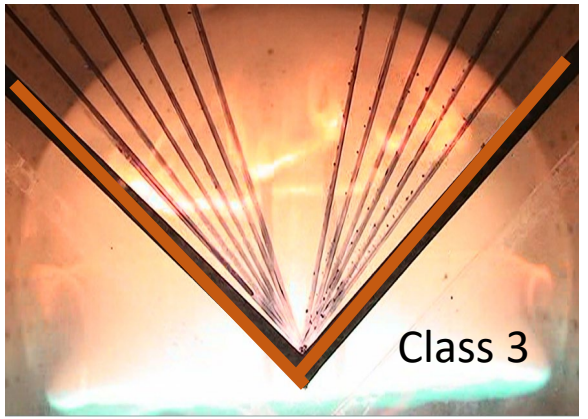
ASTM E681 Test Examples

- Flame spread **> 90°** indicates “flammability”
- Based on the spread beyond **90°**, as well as the **speed at which the flame spreads**, defines the degrees of ‘flammability’
  - 2L – lower flammability
  - 2 – flammable
  - 3 – higher flammability









Comparison of Flammability Parameters

Refrigerant ASHRAE Designation	R-454C GWP 148 / Fourth Climate Assessment Report (AR4)	Propane(R-290) GWP 3 Fourth Climate Assessment Report (AR4)	
ASHRAE Safety Group	A2L	A3	Risk Trend
Lower Flammability Limit (LFL) (Grams/square meters)	292	38	LFL ↑, Risk ↓
Minimum Ignition Energy (MIE) (Megajoules)	300 - 1000	0.25	MIE ↑, Risk ↓
Burning Velocity (S_u) (centimeters/second)	1.6	46	S_u ↓, Risk ↓
Heat of Combustion (HOC) (Kilojoules/gram)	10.5	46.3	HOC ↓, Risk ↓

More favorable flammability parameters can lead to lower ignition risk!

A2Ls and A3 Comparison

A2Ls' LFL is ~ 8x higher than that of R-290	→	A2L are less likely to form flammable concentrations → Allowing larger charge sizes for larger applications
A2Ls' MIE is significantly higher (400-1,000x)	→	A2Ls are harder to ignite → Safer to use with many commonly used electrical components
A3s' HOC is 4 to 5x higher than that of an A2L refrigerant	→	A2L are less reactive & have lower combustion energy → Hence, A2L's generate "lower severity" ignition events

Opteon™ Refrigerants

Chemours™

Codes and Standards

Product Design Standards

UL 60335-2-40, 3rd Edition (Air Conditioning (AC) Applications)

- Enables the use of A2L systems
  - Up to 260*LFL (≈ 78 kilogram (kg))
    - Dependent on mitigation requirements
- 4th edition to publish later this year
  - Updates based on industry research

UL 60335-2-89, 2nd Edition (ComRef Applications)

- Enables the use of A2L systems
  - Up to 260*LFL (≈ 78 kg)
    - Dependent on mitigation requirements
- Work on 3rd edition expected to start once 4th edition of UL 60335-2-40 publishes

Application Standards

ASHRAE Standard 15, 2019 Edition (General Safety Standard)

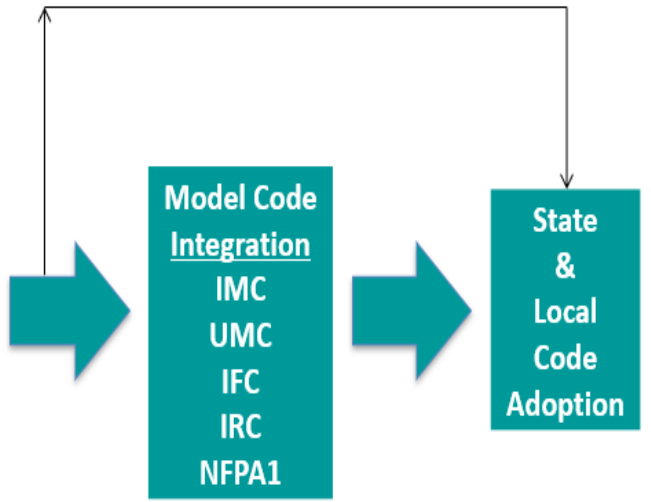
- A2Ls broadly enabled in 2016 Edition
  - Addendum d (2016) – Human Comfort
  - Addendum h (2016) – Machine Rooms

- Refrigeration requirements not adequately addressed
  - Addendum l (2019) address flammables in refrigeration applications
    - Up to 13*LFL for A2s & A3s
    - Up to 260*LFL for A2Ls
    - Consistent with requirements of UL 60335-2-89 2nd Edition
    - Approved for 3rd PPR – expected to publish later this year

US Building Codes

- Model codes developed for adoption by state & local governments
  - International Code Council (ICC) publishes I-Codes - includes International Mechanical Code (IMC), International Residential Code (IRC), & International Fire Code (IFC)
    - Used by most states
  - International Association of Plumbing & Mechanical Officials (IAPMO) – publishes Uniform Mechanical Code (UMC)
    - Used by a handful of states (e.g., California)
  - National Fire Protection Association (NFPA) 1 (Old Fire Code)
    - Used by some states/localities instead of IFC
- Model codes developed on 3-year cycle
  - States have different options for updating codes using varying timetables

Standard Type	USA Standards
Refrigerant Classification	ASHRAE 34 UL 2182
General Safety (Horizontal)	ASHRAE 15 ASHRAE 15.2P
Equipment Specific (Vertical)	UL 60335-2-24 UL 250 UL 60335-2-40 UL 474 UL 484 UL 1995 UL 60335-2-89 UL 427 UL 471



Opteon™ Refrigerants

Chemours™

Opteon™ Refrigerants

Chemours™

TEWI and Installation Example

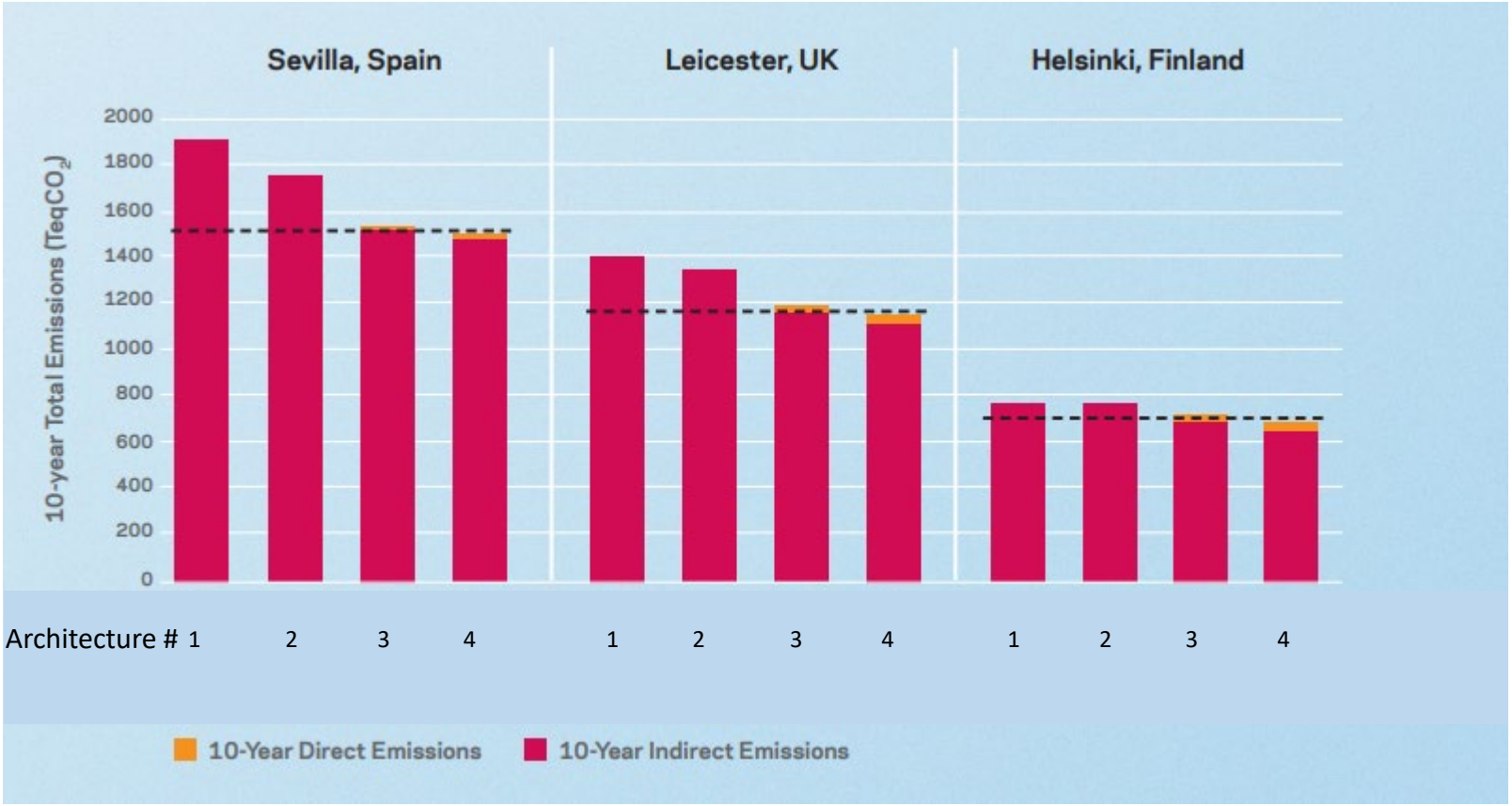
Indirect and direct carbon emissions for A2L refrigerants

2,000 square meters (m^3) [70,629 square feet (ft^3)] store area

160 kilowatt (kW) (45 tons) medium temperature (MT) load with an evaporating temperature (SST) of -9 °C (15.8 °F)

30 kW (8.5 tons) LT load with an SST of -33 °C (-27.4 °F)

Temperature profiles for warm (Sevilla), moderate (Leicester) and cool (Helsinki) European Union (EU) climates dictated the condenser temperature



Architecture #:
1: Carbon Dioxide (CO_2) Booster 2: CO_2 Booster + Ejector 3: R-454A 4: R-454C

A2Ls provide efficient refrigerant options to the commercial refrigeration sector

Opteon™ Refrigerants

Chemours™

Cold Storage A2L Installation

- 1805 m^3 bakery needing to maintain a -30 ^oC suction temperature

- R-454A (AR4 GWP 238) was selected for the trial due to the close thermodynamic performance match to R-404A

*Equipment installed:

Zanotti HCU1580B941J Condensing Units
Bitzer 4HE-18Y-40P semi hermetic compressors
Danfoss thermostatic expansion (TE5) R-407A/F thermostatic expansion valve (TEV) with a #2 orifice

- Risk assessment completed prior start up

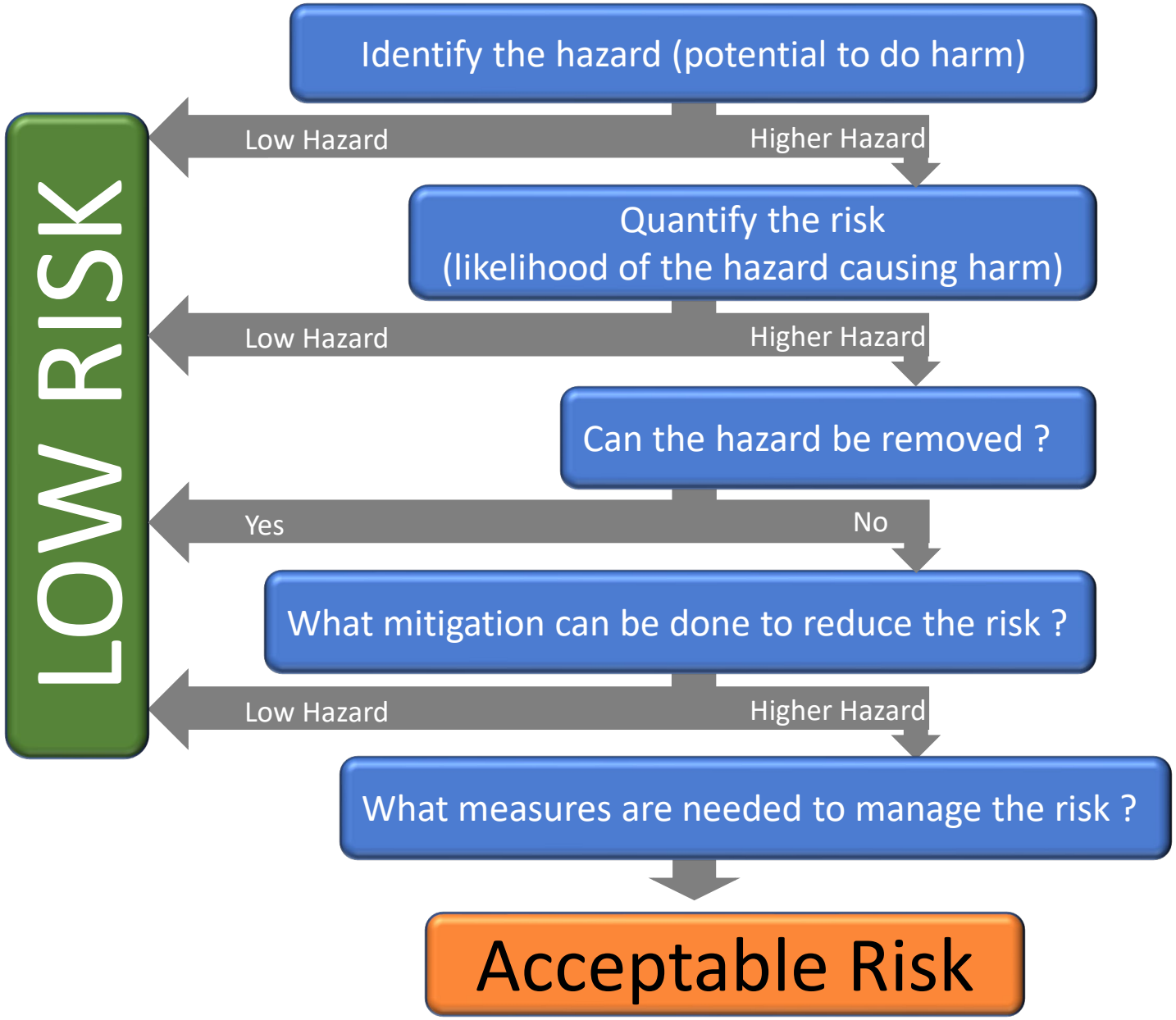
Park Cakes' new cold storage facility in Oldham, UK.

Opteon™ Refrigerants

Chemours™

Basic Risk Assessment Process

Risk assessments are required for **ALL** refrigerants including the A1 safety classification



The risk assessment should be based on a step-by-step appraisal of whether a release may occur, and the consequences of that release and any undesirable occurrence arising from it, at least covering the following activities:

- Specific working procedures
- Handling
- Storage
- Transportation

Opteon™ Refrigerants

Chemours™

Charge Size

- EN378 defines three access categories →
  a) General access
  b) Supervised access
  c) Authorized access

- Four location categories →
  Class I, Mechanical equipment located within the occupied space
  Class II, Compressors in machinery room or open air
  Class III, Machinery room or open air
  Class IV, Ventilated enclosure

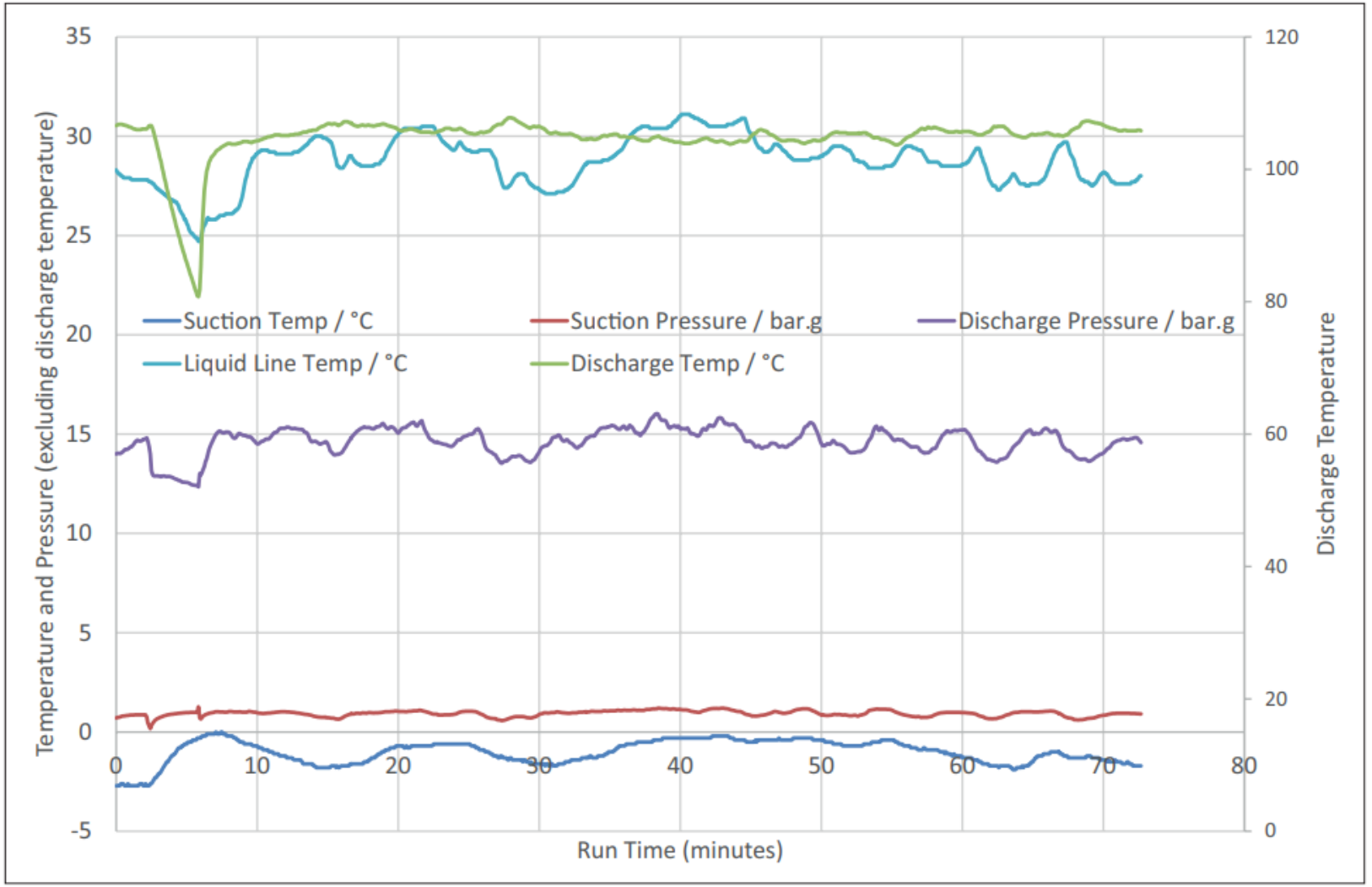
- The bakery installed a machine room outside and the cold store had restricted access giving the bakery a Class II category c classification

- For an occupancy level of <1 person/ 10m^2 there was no charge limit in this situation but for a greater occupancy level the charge limit would have been 25 kg)

- 23 kg charge required for this system design

Condensing Unit Performance

- Different from HFCs: Risk assessment of A2Ls, charge size calculations
- Similar to HFCs: Controls, performance, equipment



Opteon™ Refrigerants

Chemours™

Conclusions

- The A2L flammability classification has significant differences in flammability properties from the A3 classification
- Codes and standards development work is ongoing
- There are highly efficient A2L alternatives for low temperature and medium temperature refrigeration applications that have historically used products like R-404A/R-448A/R-449A
- A2L refrigerants reduce scope 1(Direct) and scope 2 (Indirect) emissions when compared to legacy products
- Europe has been leading the way with using A2Ls in commercial refrigeration, however, North America will soon follow in support of meeting the HFC phase down under AIM

Contacts and Upcoming Webinars

Presenter Contacts

- Andrew Pansulla, Chemours
  andrew.r.pansulla@chemours.com
- Brandon Marshall, Chemours
  brandon.marshall@chemours.com
- Mitch Newsome, Chemours
  mitch.newsome@chemours.com
- Charles Allgood, Chemours
  charles.c.allgood-1@chemours.com

GreenChill Contacts

- Kersey Manliclic, U.S. EPA
  Manliclic.Kersey@epa.gov

Upcoming Events

Date	Webinar Topic
6/15/2022	Refrigerant Banking
6/21/2022	Food Retail Refrigeration Leaks: Exploring the True Cost and Equipment Specification Solutions

Join our webinar invitation list or request today's slides: EPA-GreenChill@abtassoc.com

Access past webinar slides: www.epa.gov/greenchill/events-and-webinars