Flammable Refrigerants

The Evolving Code Impact

2019 Fire Prevention Institute
Washington State Association of Fire Marshals

Your Instructor

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Course Goal

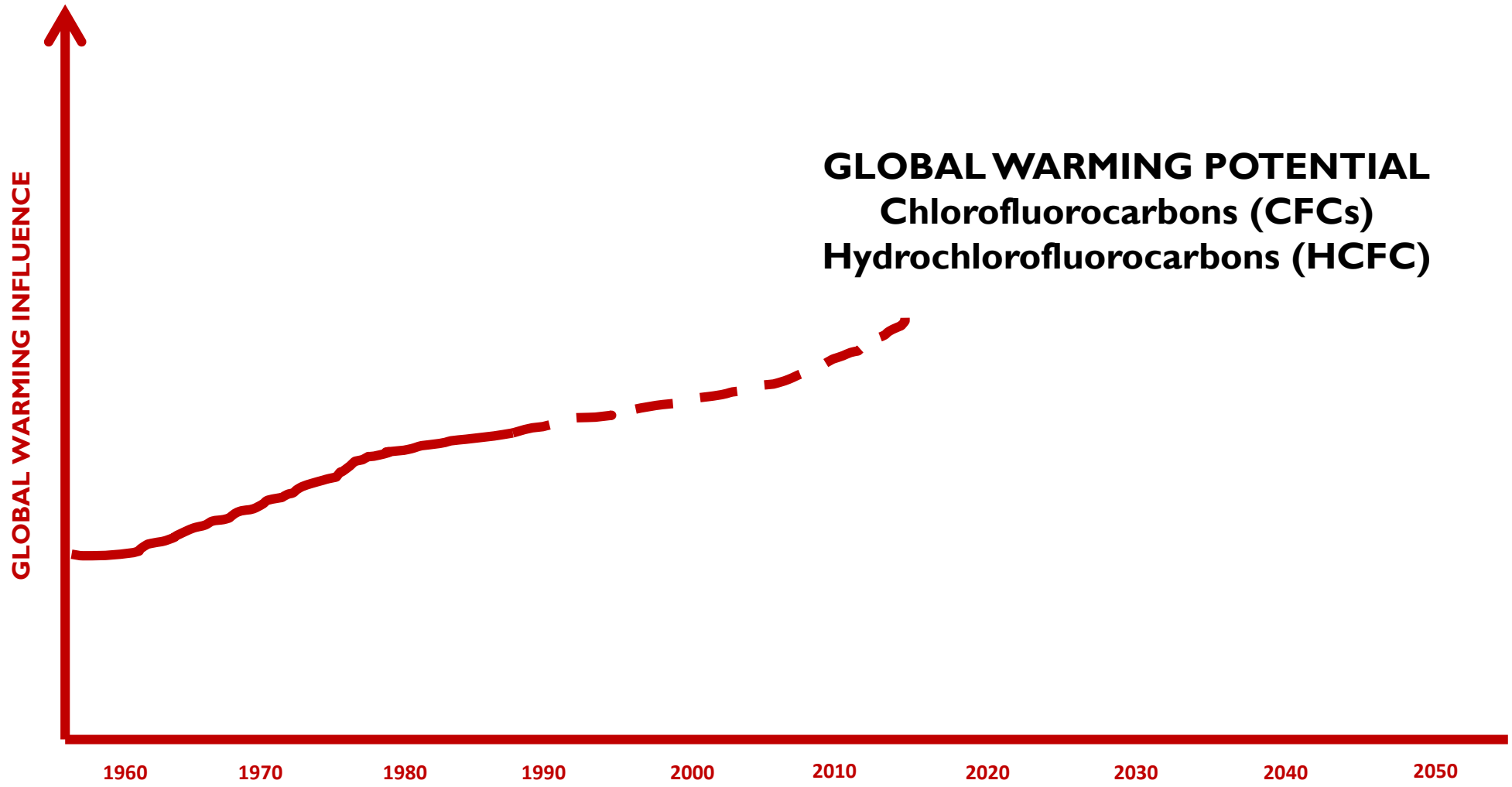
Explore the changing refrigerant environment and its impact on codes.

Learning Objectives

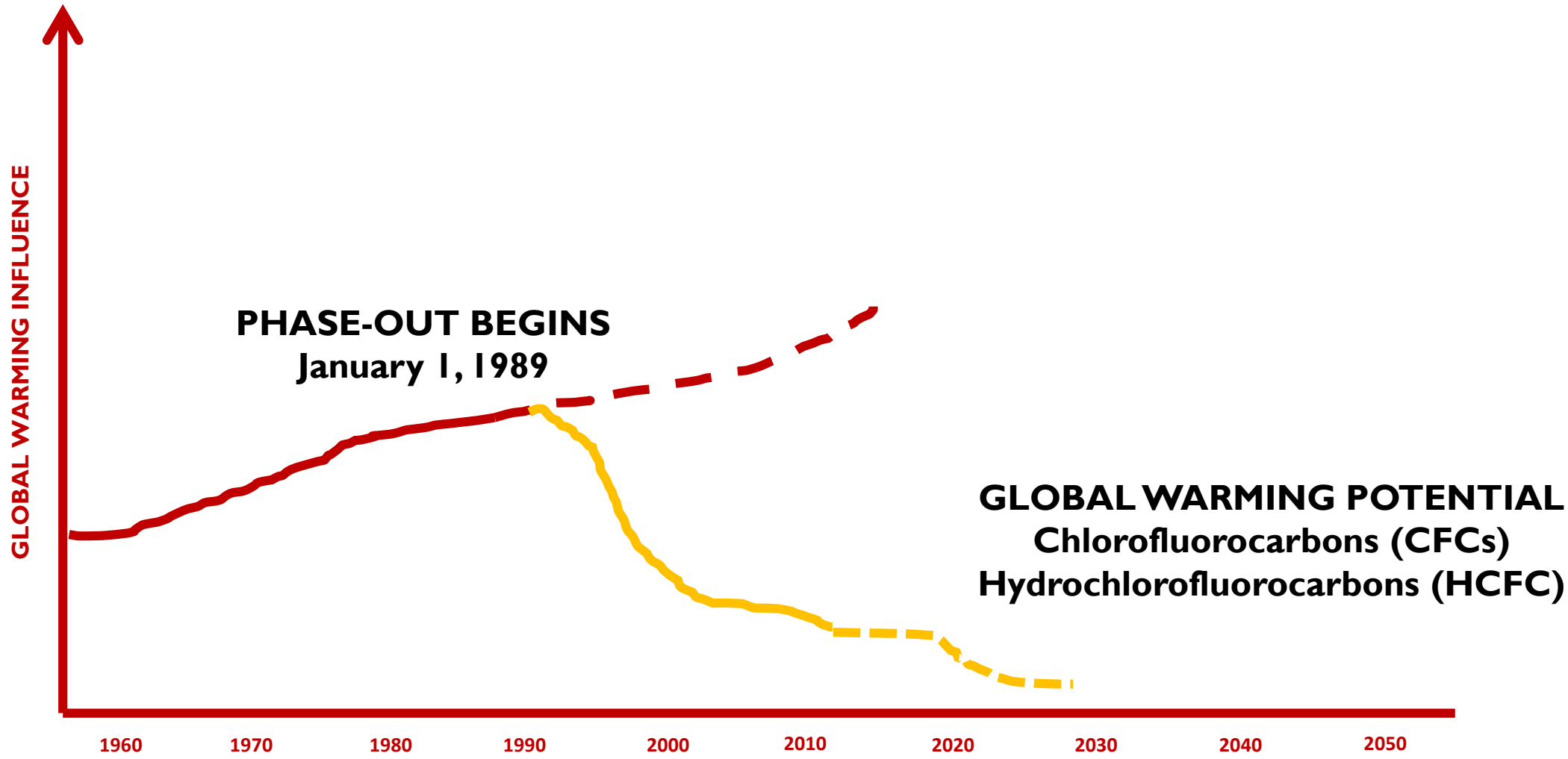
At the end of the presentation, you will be able to:

- Identify environmental and code issues associated with the refrigerant gas changes.
- Describe simple refrigeration physics, terminology and chemistry.
- Identify recent changes in refrigeration gas nomenclature.
- Identify IFC® § 605 requirements (2018 edition).

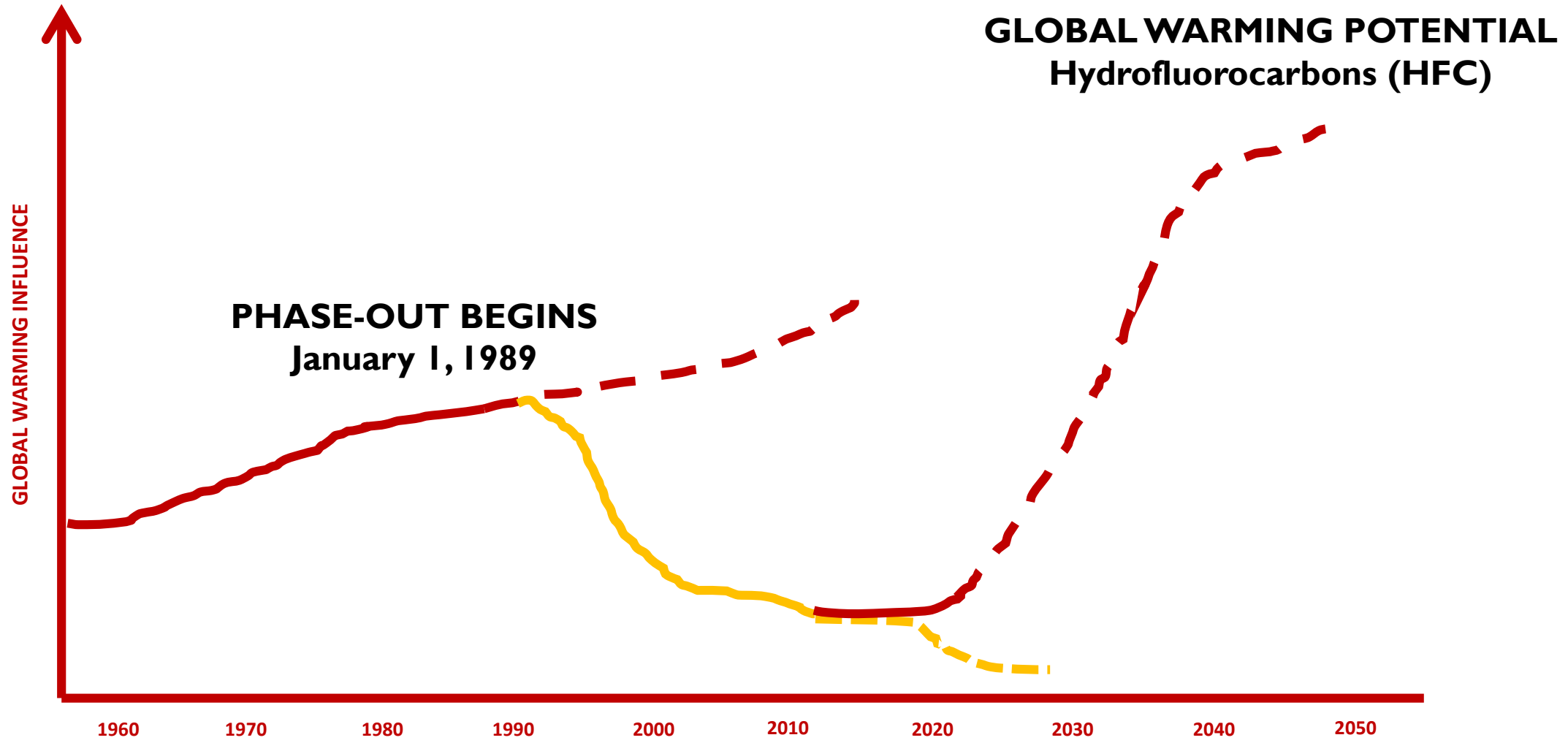
Why Change?



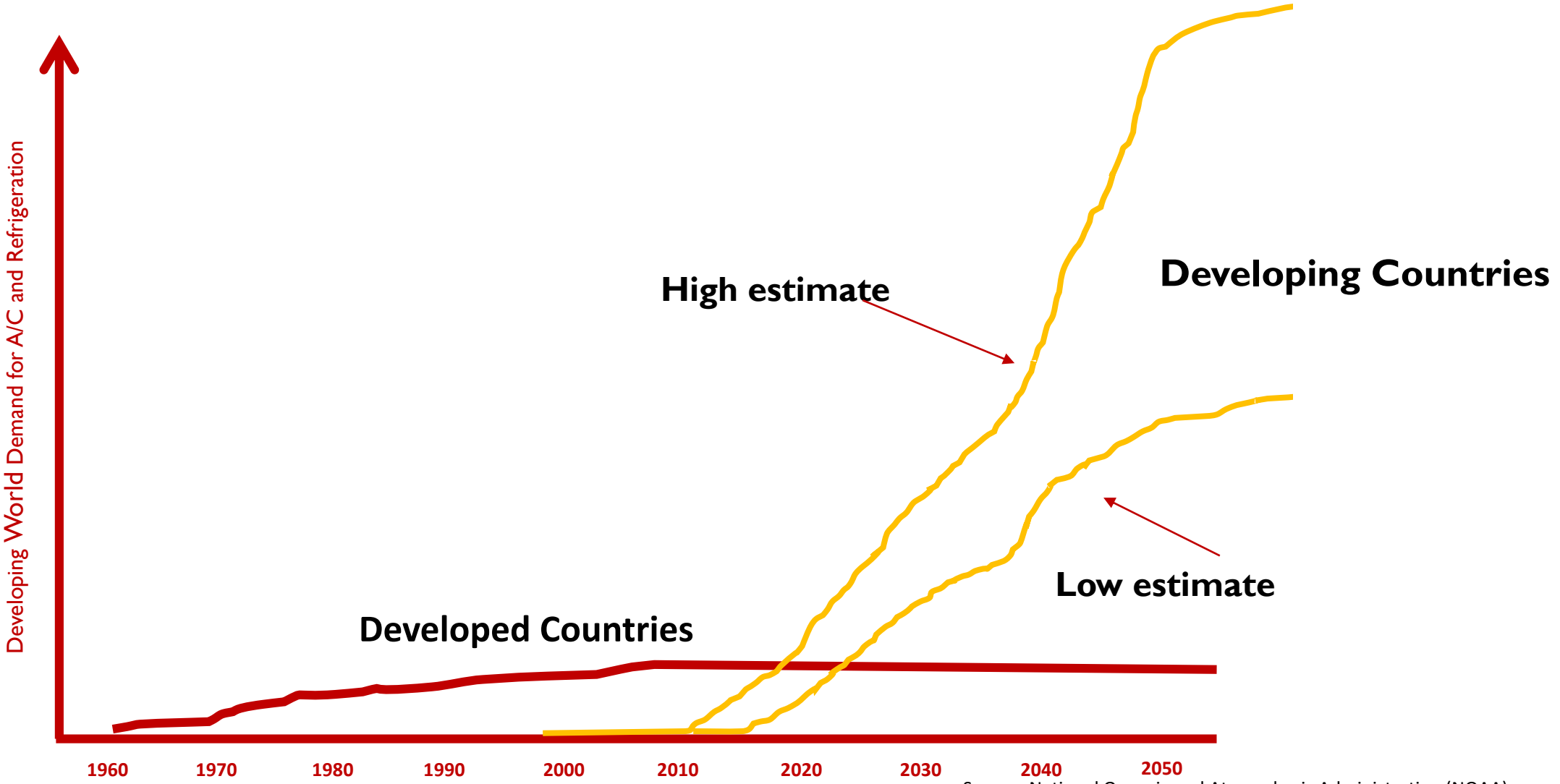
Montreal Protocol



Hydrofluorocarbons

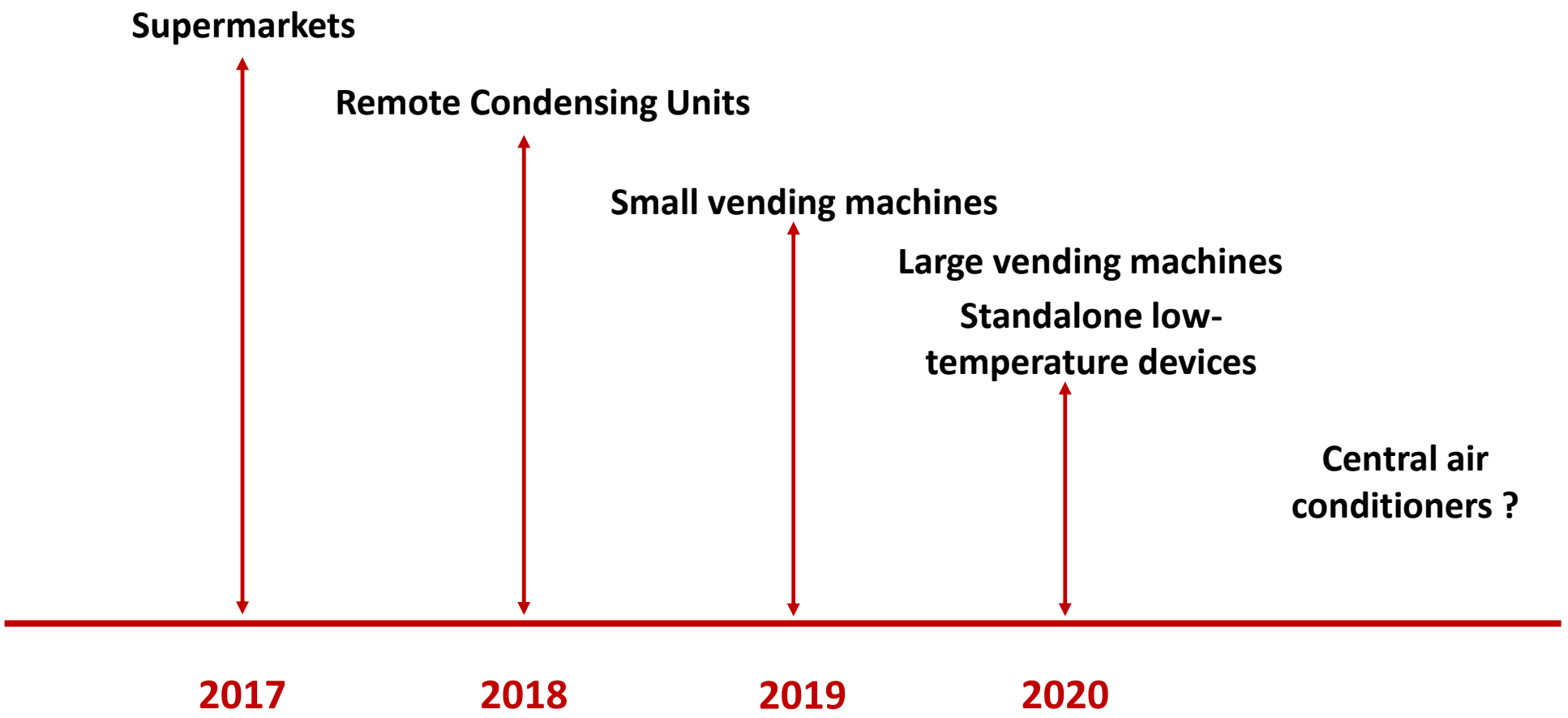


Global Demand



Source: National Oceanic and Atmospheric Administration (NOAA)

US: GWP Proposed Phaseout (EPA)



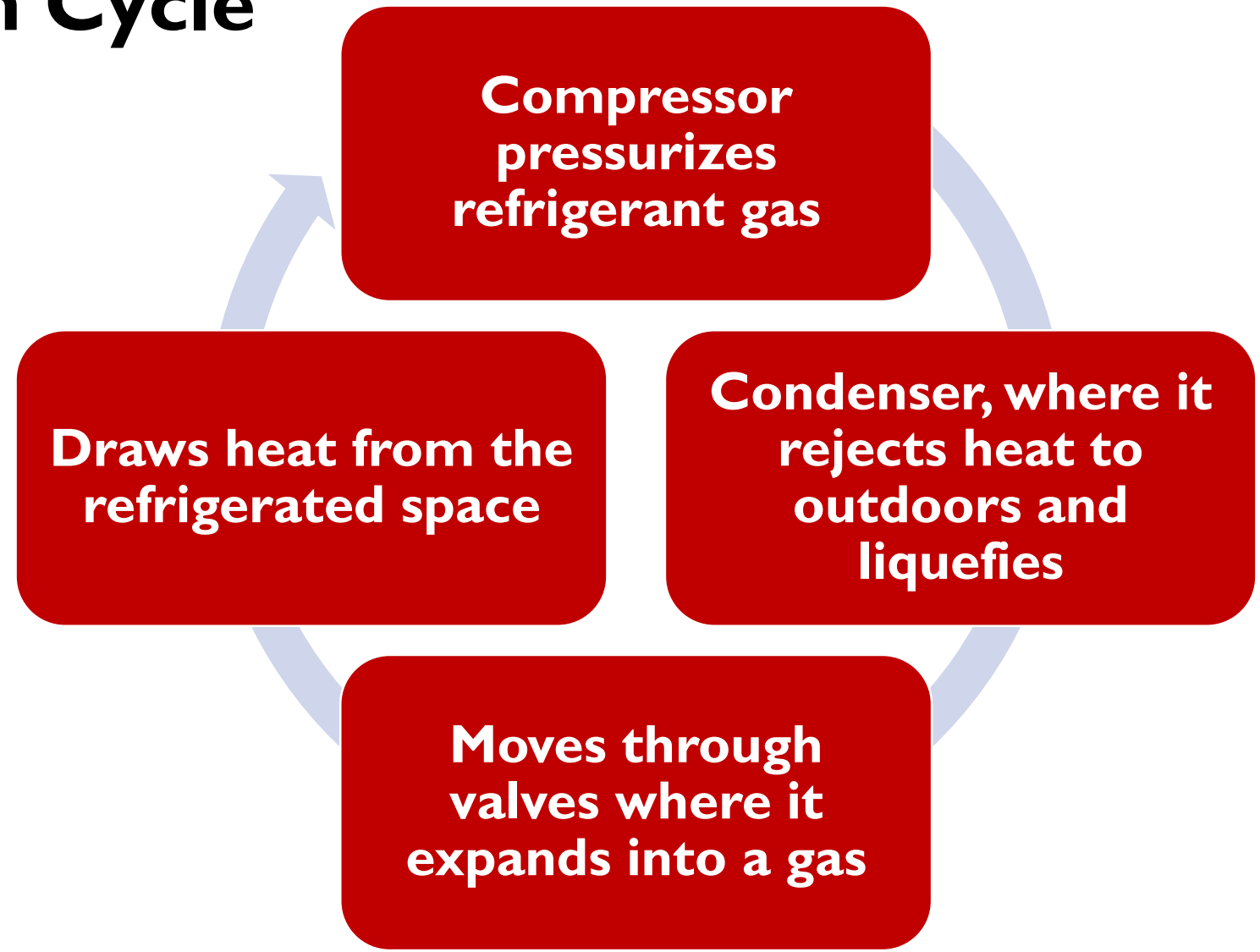
Refrigeration Principles: Heat Properties

- Always moves from warmer to cooler surface
  - Moves by radiation, convection or conduction
- When a refrigerant boils it absorbs heat
- When a refrigerant condenses, it releases heat
- *Heat by a fluid (refrigerant) -- as it changes from a liquid to a gas -- lowers the temperature of the objects around it.*

Heat Terminology

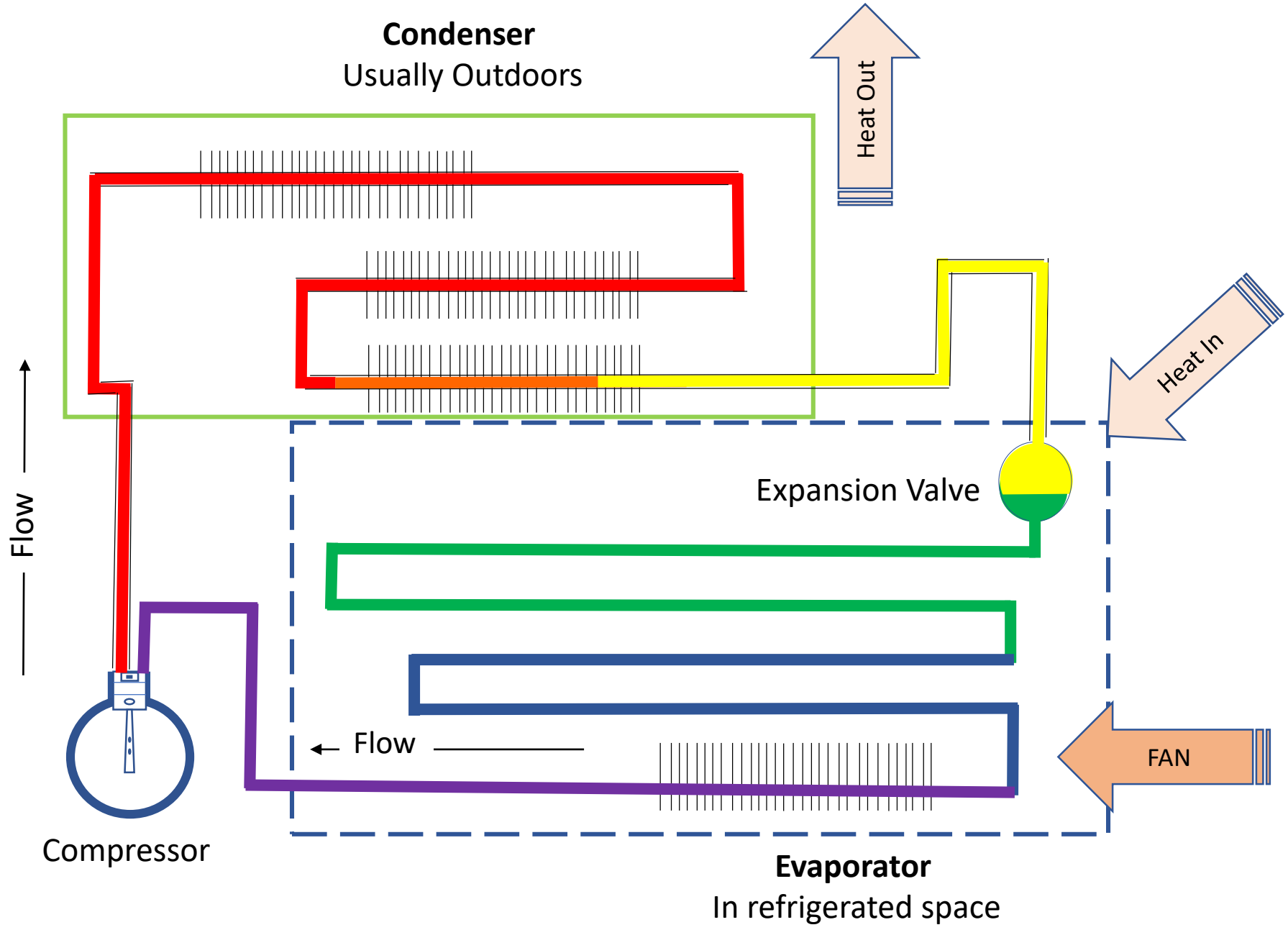
- Specific heat
  - Amount of heat per unit mass required to raise the temperature by one (1) degree Celsius (1.8°F).
    - Used to calculate capacity requirements for refrigerating known quantities of product
- Latent heat
  - Amount of heat absorbed or released by a substance undergoing a change of state (such as changing ice to water or water to steam) at constant temperature and pressure
    - Occurs in evaporator and drives the cooling process

Refrigeration Cycle



Schematic Only
Not To Scale

- High Pressure Gas
- High Pressure Liquid
- Low Pressure Gas/Liquid
- Low Pressure Vapor



Refrigerant Units

Source: Livescience.com

- Refrigerant *ton*
  - Measure of *cooling capacity* -- not refrigerant.
    - Energy removal rate that will freeze one short ton of water at 32 °F in one day.
    - Historically defined as approximately 11,958 Btu/hr, and now conventionally redefined as exactly 12,000 Btu/hr.

Refrigerant Capacities

- Residential A/C equipment

Source: AC 2015.com

Tons	kW	Btu/Hour
1-5	3.5.-17.5	12,000 – 60,000

- Commercial industrial chiller systems

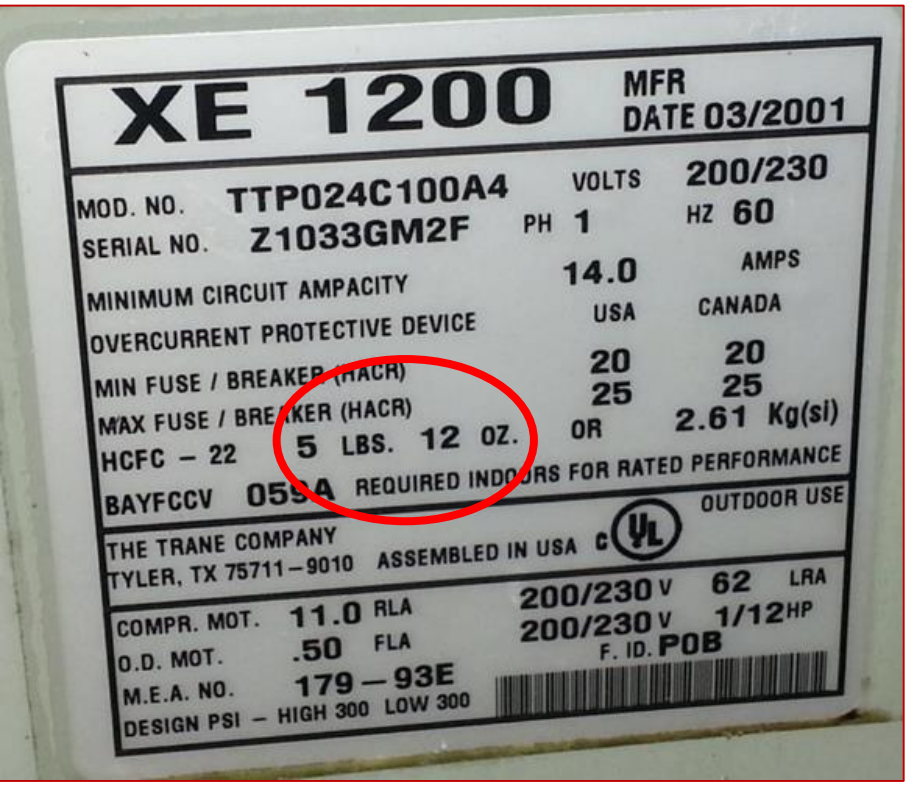
Source: Excaliburlpa.co.uk

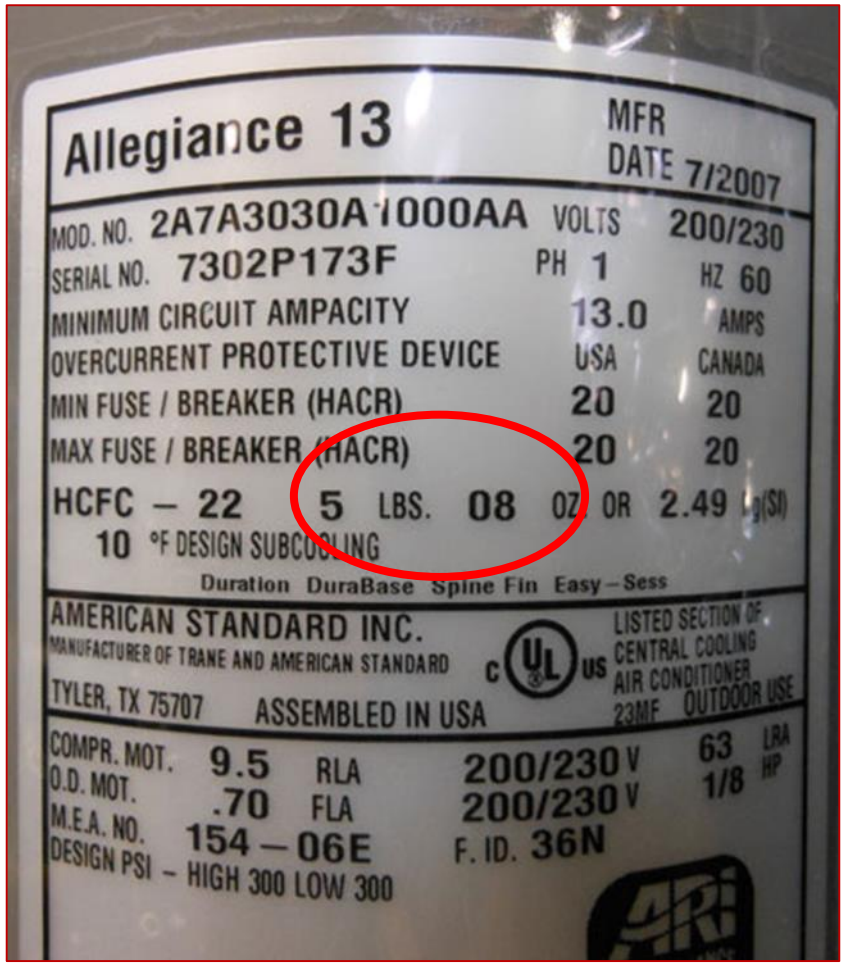
Tons	kW	Btu/Hour
Up to 800	2,800	9,600,000

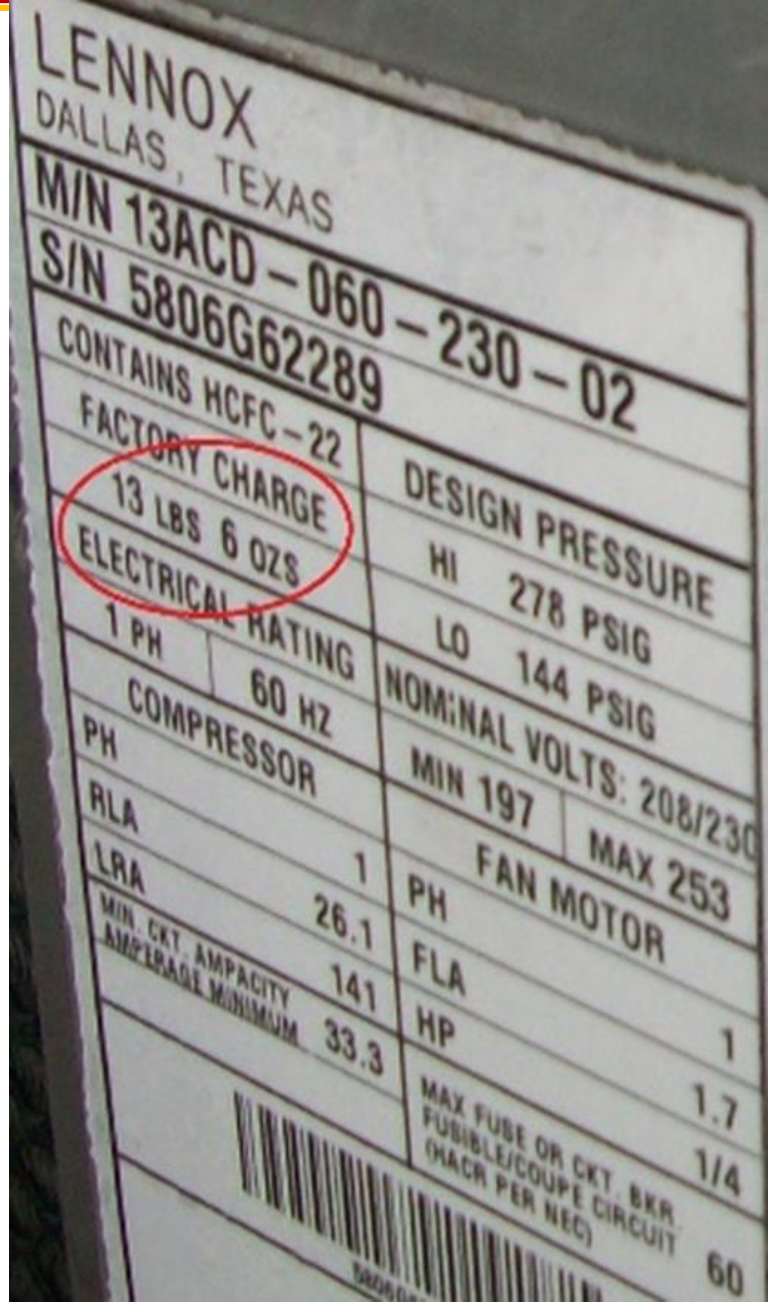
Refrigerant Pounds

- For *code* purposes, refrigerants are measured in *pounds*
  - Liquid weight unit
  - Refrigerants typically have density >1
    - Heavier than water
    - Densities lessen at higher temperatures
  - Based on internal volume of the refrigeration system
    - Volume x liquid density at specific temperature = pounds in system
  - Check the system label.

Refrigerant Labels







Sidebar: Note to First Responders

- For *response* purposes, vapor density should be considered
  - Most refrigerant leaks occur as vapor
    - Vapor density > 1 = vapor sinks
    - Vapor density < 1 = vapor rises

Source: U.S. Chemical Safety Board

Optimal Refrigerant

- Should have low boiling point and low freezing point.
- Must have low specific heat and high latent heat.
  - high specific heat decreases the refrigerating effect per pound of refrigerant, and,
  - high latent heat at low temperature increases the refrigerating effect per pound of refrigerant.

Refrigerant Composition

Prefix	Represents	Examples
R	Refrigerant	R22, R134a, R717

May include:

C	Chlorine	RC317: Chloroheptafluorocyclobutane
B	Bromine	R22B1: Bromodifluoromethane
F	Fluorine	RFE-36: Hexafluoropropane
H	Hydrogen	R134a: 1,1,2,2-Tetrafluoroethane
C	Carbon	RC318: Octafluorocyclobutane
E	Ether	RE170: Dimethylether

Refrigerant Numbering System

- R(efrigerant)
  - > 1st digit: Number of double carbon bonds
    - > 2nd digit: Carbon atoms minus 1
      - > 3rd digit: Hydrogen atoms plus 1
        - > Last digit: Fluorine atoms

Hydrocarbons/Halocarbons

R134a*: Tetrafluoroethane – CH_2FCF_3

*a = Isomer stability.

R	N of double carbon bonds (Placeholder omitted when zero)	Carbon Atoms (Minus 1)	Hydrogen Atoms (Plus 1)	Fluorine Atoms (N/molecule)
R	0	1	3	4

Activity

What is chemical composition of R22: Chlorofluoromethane – $CHClF_2$?

R	N of double carbon bonds (Placeholder omitted when zero)	Carbon Atoms (Minus 1)	Hydrogen Atoms (Plus 1)	Fluorine Atoms (N/molecule)
R	0	1-1=0	1+1 = 2	2

Refrigerant Designations

Numbering Series	Chemistry	Examples
000, 100, 200	Hydrocarbon-based	HCFC-22, HFC 134a, R290 (propane)
400	Zeotropes	R-404A
500	Azeotropes	R-507A
600	Organic	R-600a (isobutane)
1000	Unsaturated organics	HFO-1234yf*

Detailed list at: https://www.ashrae.org/technical-resources/standards-and-guidelines/ashrae-refrigerant-designations

Refrigerant Chemical Nomenclature

- Azeotrope
  - *Stable blend of two or more refrigerants* with similar boiling points that act as a *single fluid*.
    - Boiling point may be higher or lower than components.
    - *Examples*:
      - R-500 (73.8% R12 and 26% R152)
      - R-502 (8.8% R 22 and 51.2% R115)
      - R-503 (401.1% R23 and 59.9% R13)

Refrigerant Chemical Nomenclature (con't)

- Zeotrope
  - *Mixture of two or more refrigerants with different boiling points.*
    - Individual components do not evaporate or condense at same temperature.
      - Evaporates/condenses of temperature range called "glide."
    - *Examples:*
      - Nitrogen, methane, ethane, propane and isobutane.

Legacy Refrigerants

Classification	Denomination	Formula	Safety Classification
Inorganics			
R717	Ammonia	NH_3	B2
R718	Water	H_2O	A1
Hydrocarbons			
R170	Ethane	CH_3CH_3	A3
R290	Propane	$CH_3CH_2CH_3$	A3
Halocarbons			
R11	Trichlorofluormethane	CCl_3F	A1

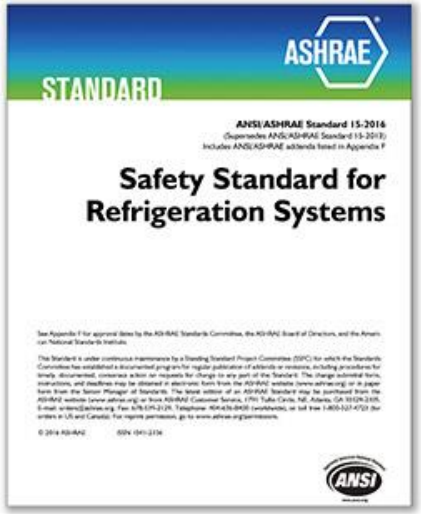
ASHRAE 15 and 34/IIAR 2 and 7

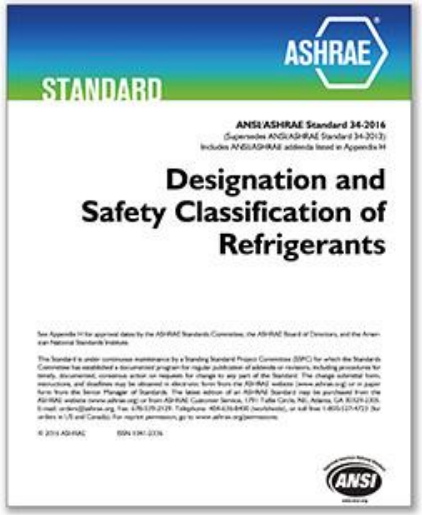
American Society of Heating, Refrigeration and Air-conditioning Engineers

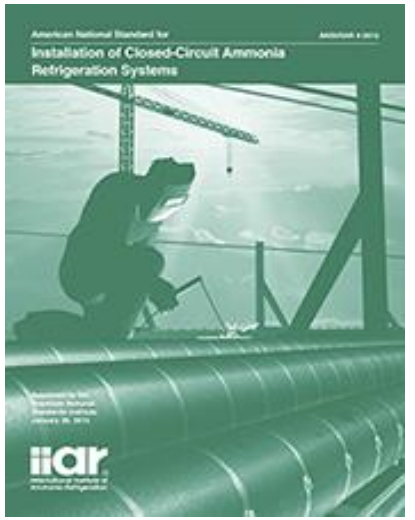
- ASHRAE 15 – Safety Standards for Refrigeration Systems
- ASHRAE 34 – Designation and Safety Classification of Refrigerants

International Institute of Ammonia Refrigeration

- IIAR 2 –Safe Design of Closed-Circuit Ammonia Refrigeration Systems
- IIAR 7 – Developing Operating Procedures for Closed-Circuit Ammonia Refrigeration Systems







NEW: ASHRAE Safety Groups

Flammability Classification	Toxicity Group	
	Group A	Group B
	Lower Toxicity	Higher Toxicity
Higher Flammability	A3	B3
Lower Flammability	A2	B2
Low Flammability	A2L	B2L
No Flame Propagation	A1	B1

Increasing Flammability

Increasing Toxicity

NEW: ASHRAE Safety Groups -- *Flammability*

Flammability Classification			
		Test	
		At 70F and 14.7 psi	Examples
A3	Higher Flammability	LFL <0.00624 lb/ft^3 Latent heat > 8172 Btu/lb	Methane Propane Butane
A2	Lower Flammability	LFL > 0.00624 lb/ft^3 Latent heat < 8172 Btu/lb	HCFC-142b HFC-152b
A2L		Difficult to ignite Flame speed < 3.94”/sec	R-32 R1234yf
A1	No Flame Propagation	No flame propagation in air	CFC-11 CFC-113 R-500

Increasing Flammability

ASHRAE Safety Groups -- Toxicity

Toxicity Groups			
Group A	Examples	Group B	Examples
Lower Toxicity		Higher Toxicity	
No toxicity identified at concentrations ≤ 400 ppm		Evidence of toxicity at concentrations <400 ppm	
A1	CFC, HCFC,	B1	Seldom used
A2	R152a	B2	Seldom used
A2L	Most Low-GWP HFC	B2L	Ammonia
A3	Hydrocarbons	B3	Hydrocarbons

Increasing Toxicity

New Refrigerants

Although nominally flammable, ventilation seems to be most effective protection strategy.

Classification	Denomination	Formula	Safety Classification
Hydrochlorofluorocarbons			
R22	Chlorodifluoromethane	$CHClF_2$	A1
Hydrofluorocarbons			
R125	Pentafluorethane	CHF_2CF_3	A1
R32	Difluoromethane	CH_2F_2	A2L
Hydrofluorolefins			
R1234ze	1,3,3,3-Tetrafluoroproene	$C_3H_2F_4$	A2L
R1234yf	2,3,3,3-Tetrafluorpropene	$C_3H_2F_4$	A2L

Refrigeration Systems Codes and Standards

Local Approaches to Regulation

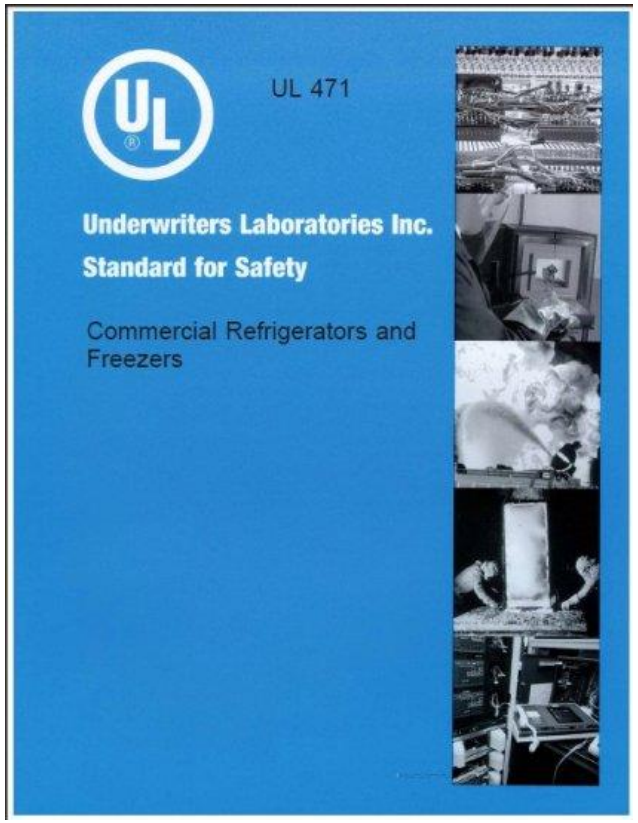
2018 International Building Code®

- Refrigerant machinery room
  - Separation -- §509/Table 509
    - One-hour separation or sprinklers and smoke separation
  - Egress -- §1006.2.2.2
    - Rooms > 1,000 ft^2: two exits or exit access
    - All portions of room within 150 feet of exits or exit access
    - Exit or exit access doors swing in the direction of egress

2018 Code Requirements (continued)

- International Mechanical Code®
  - Installation permit -- §106.1
- International Fire Code®
  - Operational permit -- §105.6.42
  - Gas detection installation permit -- §105.7.11
  - Installation and operation -- §605

Additional Reference Standards



- UL 207
  - *Standard for Refrigerant-Containing Components and Accessories, Nonelectrical*
- UL 412
  - *Standard for Refrigeration Unit Coolers*
- UL 471
  - *Standard for Commercial Refrigerators and Freezers*
- UL 1995
  - *Heating and Cooling Equipment*

International Mechanical Code®

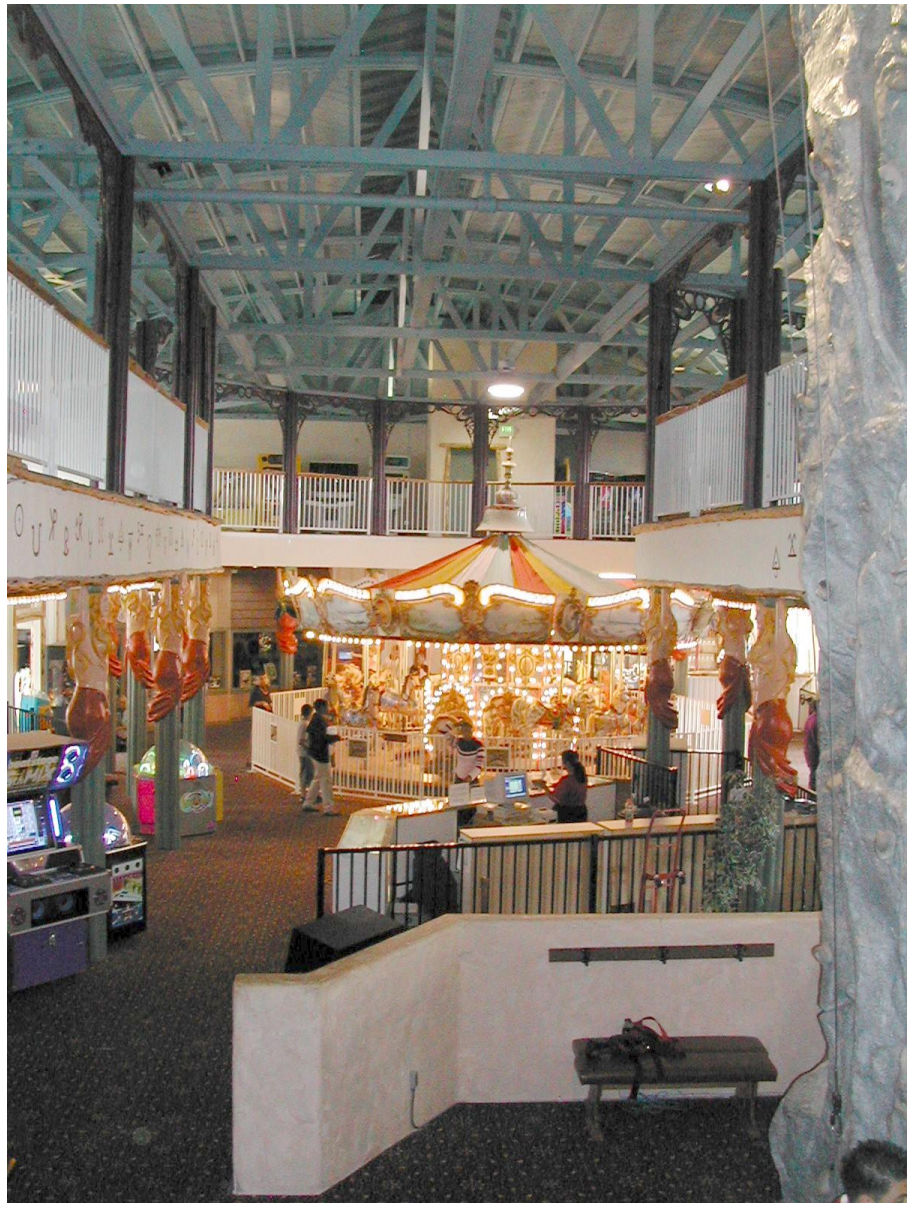
- Chapter 11 **REFRIGERATION**
  - Design, installation, construction and repair
  - Six-step design protocol

Courtesy: Arescobuyersclub.com

Courtesy: Hussung.com

1103.2 IMC® Design Protocol

1. Occupancy classifications
    - Institutional
    - Public assembly
    - Residential
    - Commercial
    - Large mercantile (O.L. > 100)
    - Industrial
    - Mixed occupancies



IMC ® Design Protocol (cont'd)

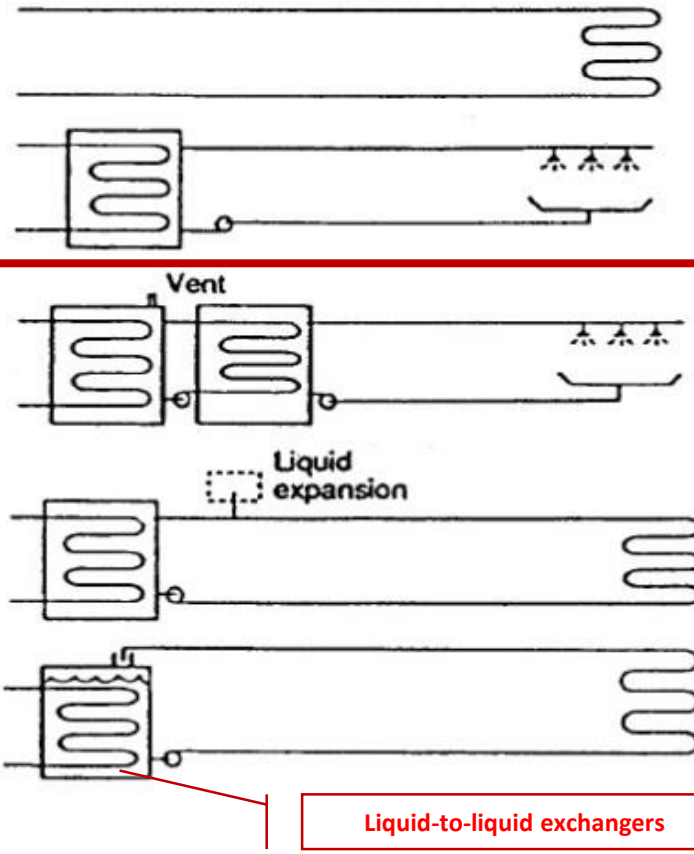
- Refrigeration system's *classification* based on likelihood leaks entering occupied area
  - Low or High probability
    - Low probability:
      - Double-indirect open spray
      - Indirect closed
      - Indirect-vented closed
    - High probability
      - Direct
      - Indirect open spray

System Classifications

High Leak Probability

Low Leak Probability

Designation	Cooling or Heating Source	Air or Substance to be Cooled or Heated
Direct system		
Indirect open spray system		
Double indirect open spray system		
Indirect closed system		
Indirect vented closed system		



IMC® Design Protocol (cont'd)

2. Refrigerant classification (A1-B3)
3. Maximum refrigerant quantity per refrigerant, system classification and occupancy
4. System enclosure requirements
5. Refrigeration and application location and installation
6. Non-factory tested, field erected equipment and appliances

IMC ® System Application

- § 1104.2 Machinery rooms
  - Outdoor applications
  - Small quantity listed equipment
- Institutional applications
  - 50% limit on refrigerants
- Industrial occupancies and refrigerated rooms
  - Exceptions for manufacturing, food and beverage prep, meat cutting and storage

Courtesy: Texas Glacier.com

IMC® Machinery Rooms

Courtesy: sirayooth.com

- § 1105
  - Design and construction
  - Ventilation requirements
    - Normal/emergency
- § 1106
  - Continuous ventilation for NH_3
  - Emergency ventilation for A2L matches IFC®
  - Remote emergency shutoffs

Refrigerant Piping §1107

- Height above floor
- Limited building envelope penetrations
- Material limits
  - Steel, copper, brass, aluminum
- Valve identification

Courtesy: Stellar.net

2018 International Fire Code®

- Section 605 **MECHANICAL REFRIGERATION**
  - Processed by PMG Code Action Committee [M] and Fire Code Action Committee
  - *Operational* permit required §105.6.40
  - For emergency *pressure control* systems
    - Flammable, toxic or highly toxic, ammonia
    - 6.6 pounds

Courtesy: NH3plus.net

Code Evolution: 2018 IFC®

- Systems using
  - § 605.1.1 *Other than* ammonia
    - ASHRAE 15
  - § 605.1.2 *Ammonia*
    - IIAR 2 for installation
    - IIAR 7 for operation
    - IIAR 8 for decommissioning

§ 605.5 IFC® (cont'd)

- More than 220 pounds A1 or 30 pounds any other refrigerant
  - Approved fire department access at all times.

Photo courtesy: WSYRChannel 9

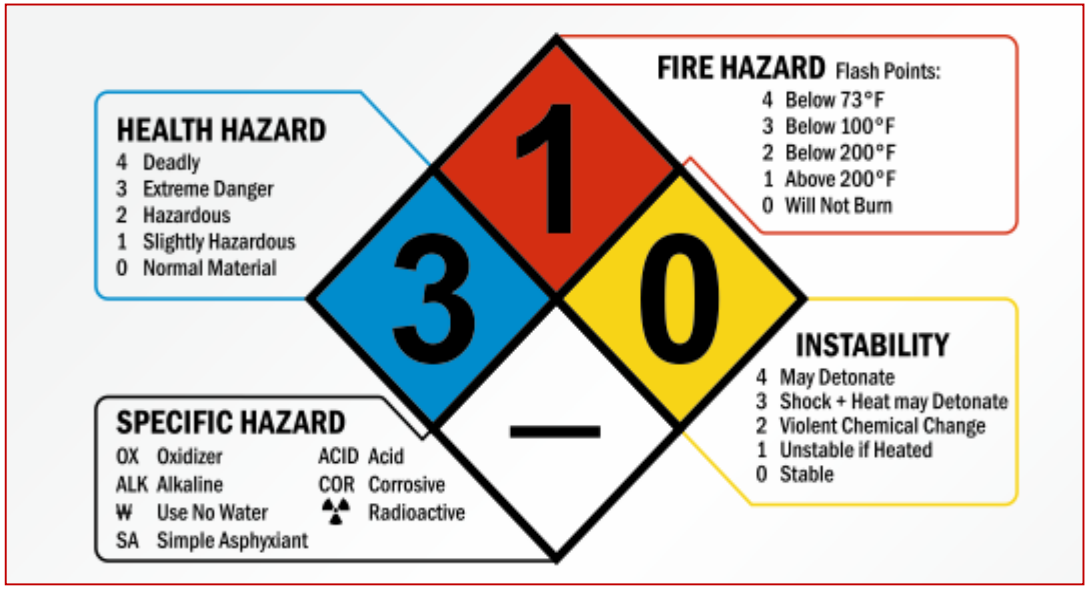
§ 605.5 IFC® (cont'd)

Courtesy: Refrigeration Today.com

- §605.4 Refrigerant change
  - Must meet IMC
- §606.6 Testing and recordkeeping
  - Treatment and flaring systems
  - Equipment in emergency refrigeration control boxes
  - Fans and equipment for emergency ventilation
  - Detection and alarm systems

§605.7 Warning Signs

- Exceed:
  - 220 pounds A1, or,
  - 30 pounds any other refrigerant
- Suitable for refrigerant
- Comply with NFPA 704



Code Evolution: 2018 IFC®

- § 605.8 Refrigerant detection
  - Machinery rooms to have audible and visual alarms
    - For ammonia, meet IIAR 2
    - For all other, § 605.8.1

Code Evolution: 2018 IFC® (cont'd)

- § 605.8.1 Refrigerants other than ammonia
  - Detector or sampling tube where refrigerant may accumulate
    - Audible/visual alarms in room, outside room and report to approved location, when detection senses *lesser of*:
    - TLV-TWA values found in IMC®, or,
    - 25% of the refrigerant LFL.

System Emergency Controls

- § 605.9 Remote controls for flammable refrigerant rooms
  - Break-glass system emergency shut OFF
  - Break-glass ventilation system ON

Courtesy: resourcecompliance.com

System Emergency Controls (cont'd)

- Flammable, toxic, highly toxic or ammonia
- § 605.10 Emergency pressure control system
  - Automatic crossover valves transfer high pressure gases to low pressure side
  - Automatic compressor stop

System Emergency Controls (cont'd)

- Flammable, toxic, highly toxic or ammonia
- § 605.11 Emergency pressure control system
  - Treatment and flaring systems

Courtesy: bhtank. com

Courtesy: Energy-Concepts. com

Code Evolution: 2018 IFC®

- § 605.17 Group A2L refrigeration rooms

  (Except NFPA 70 Class 1, Division 2 spaces)

  - § 605.8-compliant refrigerant detection system
    - At or below 25% of the refrigerant LFL,
    - Operate ventilation system, and have,
    - Supervised detection, signaling and control circuits.

Code Evolution: 2018 IFC® (cont'd)

- ASHRAE 15 or Table 605.17.2 ventilation rates

Refrigerant	Composition	Q (cfm)	Class	NFPA 704
R32	Difluoromethane	32,600	A-2L	1-4-0
R143a	1,1,1-trifluoroethane	28,700	A-2L	2-0-0
R444A	Zeotrope	13,700	A-2L	---
R444B	Zeotrope	22,400	A-2L	---
R445A	Zeotrope	16,600	A-2L	---
R446A	Zeotrope	50,700	A-2L	---
R447A	Zeotrope	50,400	A-2L	---
R451A	Zeotrope	15,000	A-2L	---
R451B	Zeotrope	15,000	A-2L	---
R1234yf	Zeotrope	16,600	A-2L	---
R1234ze(E)	Zeotrope	12,600	A-2L	---

Code Evolution: 2018 IFC® (cont'd)

- § 605.17.2 Manual shutdown only
- § 605.17.3 Ventilation discharge point
  - Outdoors at least 15 feet above grade
  - 20 feet from any window, ventilation opening or exit.

Review

- Refrigerant compositions (residential, commercial, refrigeration) are changing.
- New refrigerants are flammable (or mildly flammable).
- New refrigerant safety standards are being written and adopted.
- Flammable refrigerants may be the only option and in a time-frame shorter than will allow the building and fire codes to be fully implemented.

References

- American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE)

  www.ashrae.org

- ASHRAE Refrigerant Designations

  https://www.ashrae.org/technical-resources/standards-and-guidelines/ashrae-refrigerant-designations

- International Institute of Refrigeration

  www.iifiir.org

- Global Refrigerant Management Initiative
  - Alliance for Responsible Atmospheric Policy

  www.arap.org

- Air-Conditioning, Heating and Refrigeration Institute

  www.ahrinet.org

- Brazilian Association for HVAC-R

  www.abrava.com.br

Questions or Comments?

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