Workshop on
"Recycle & Reclaim" of Refrigerants and Emerging Alternatives in the Market

(Refrigeration & Air-Conditioning Sector)
in conjunction with OZONE Day 2018

The Saujana Kuala Lumpur
25 September 2018

MS2678:2017
Flammable Refrigerant System Code of Practice
- OVERVIEW -

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MS2678 - WG Members

1. ASHRAE Malaysia Chapter
2. Association of Consulting Engineers Malaysia
3. Daikin Research & Development (M) Sdn Bhd
4. Department of Environmental
5. Department of Occupational Safety and Health
6. Ener-Save Sdn Bhd
7. Energy Commission
8. Fire and Rescue Department Malaysia
9. Institut Latihan Perindustrian
10. Kumpulan Arena Sdn Bhd
11. Malaysian Air-Conditioning & Refrigeration Association
12. Pusat Penyelidikan Kebombaan
13. SIRIM Berhad (Secretariat)
14. The Institution of Engineers, Malaysia
15. Universiti Kuala Lumpur
16. Westech Chemicals Sdn Bhd

History of Refrigeration & Airconditioning

- 1830s - Jacob Perkins - vapor compression (ether)
- 1851 - John Gorrie - patent for air cycle
- 1859 - R-717 / R-718 (ammonia/water)
- 1866 - CO_2 - marine applications
- 1873 - R-717 (ammonia) commercial refrigeration - Carl Linde
- 1875 - R-764 (sulfur dioxide)
- 1920s -R-600a (isobutane) & R-290 (propane)
- 1922 - Willis Carrier - R-1130 (dielene)
- 1926 - R-30 (methylene chloride)

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Common Refrigerants in 1920s

Ammonia (R-717)	**NH_3**
Carbon Dioxide	**CO_2**
Sulfur Dioxide	**SO_2**
Hydrocarbons	**C_nH_m**
Methyl Choride	**CH_3Cl**
Water	**H_2O**

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EARLY REFRIGERANTS ARE EITHER FLAMMABLE OR TOXIC !

Challenge to Find Refrigerants

(before ODP & GWP)

- Non-flammable
- Good Stability
- Low Toxicity
- Atmospheric Boiling Point between -40^{0}C & 0^{0}C

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How are Refrigerants selected?

The Periodic Table

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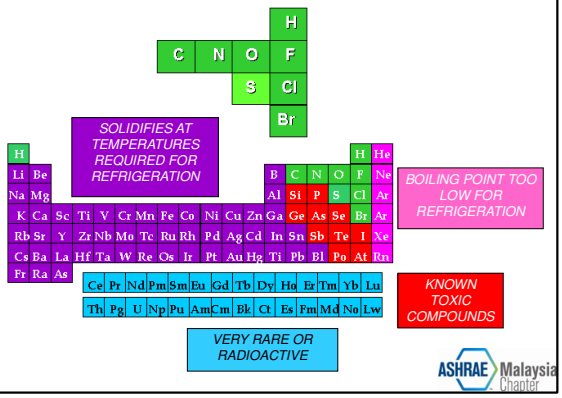
THE PERIODIC TABLE



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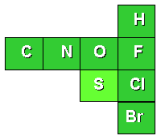

From these elements,
CFC refrigerants were formulated.

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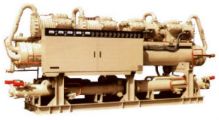
1931	CFC R12
1932	CFC R11
1936	HCFC R22
1980s	CFC, HCFC R123

CFC and HCFC extensively used as refrigerants in air-conditioning systems



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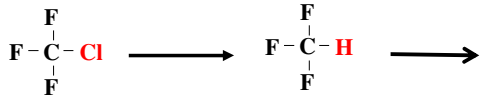
What are the potential replacements?

(post ODP & GWP)



ChloroFluoroCarbon (CFC)

HydroFluoroCarbon (HFC)

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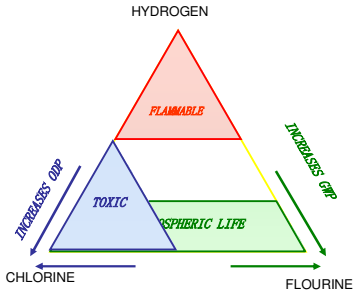
Group	Name	Elements	Commercial Name
CFC	ChloroFluoroCarbon	Chlorine, Fluorine, Carbon	R-11, R-12
HCFC	HydroChloroFluoroCarbon	Chlorine, Fluorine, Hydrogen, Carbon	R-22, R-123
HFC	HydroFluoroCarbon	Fluorine, Hydrogen, Carbon (alkane)	R-134a, R-32
HFO	HydroFluoroOlefin	Fluorine, Hydrogen, Carbon (alkene)	R-1234yf

SELECTING REFRIGERANTS (post Montreal Protocol)

- ✓ ***Physical Consideration***
  - Operating Pressure & Temperature
  - Critical Point
  - Normal Boiling Point
  - Bubble & Dew Point Temperature
  - Fractionalization (Temperature Glide)
  - Flammability
  - Toxicity
  - Operating Pressure
  - Lubrication
- ✓ ***Environmental Consideration***
  - Ozone Depletion Potential (ODP)
  - Global Warming Potential (GWP)
  - Atmospheric Lifetime
- ✓ ***Efficiency***
  - COP

Refrigerant			Property				
			Capacity ratio /gas volume	Condensation pressure kPa.a	ODP	GWP	Safety
<reference>	R22	single	100	1943	0.034	1900	O
Substitute Refrigerants	R134a	single	62	1319	0	1600	O
	R407c	Non-azeotropic	98	2111	0	1980	O
	R410a	Quasi-azeotropic	140	3066	0	2340	O
Other Refrigerants	R32	single	162	3141	0	880	Δ (low inflammability)
	Propane	single	82	1713	0	3	X (high inflammability)
	Ammonia	single	118	2033	0	0	X (high inflammability; toxic)
	CO_2	single	153	5722	0	1	O

Advantage Disadvantage



Overview - Refrigerant Progression

Today - 2018

The World Scenario:

- CFCs successfully phased out (circa 2000)
- HCFC phase out program in progress
- HFC phase down commenced
- Low GWP and mildly flammable HFC/HFOs coming on stream
- HFOs gearing up to replace high GWP HFCs
- Natural refrigerants progressing at varying pace

Overview - Refrigerant Progression

Today - 2018

The Local (Malaysia) Scenario:

- CFC gone and dusted
- HCFC phase out program in place
- HFC phase down schedule on the way
- Naturals (HC) increasingly creeping on board
- HFC-134a, HFC-410a are prevalent
- HFC-32 introduced in Indonesia begins to make its mark
- HFOs beginning to appear
- RRR practice remains insignificant
- HCs for domestic refrigerators are finally here!!

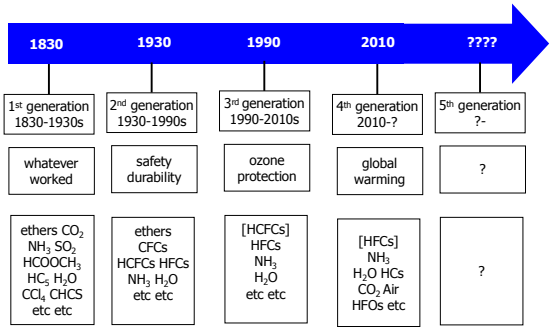
Overview - Advent of Flammable Refrigerants

The first generation of refrigerants was all about accepting anything that worked - heralding the era of Natural refrigerants

The second generation addressed concerns on safety (flammability), toxicity & durability - the era of Synthetic refrigerants

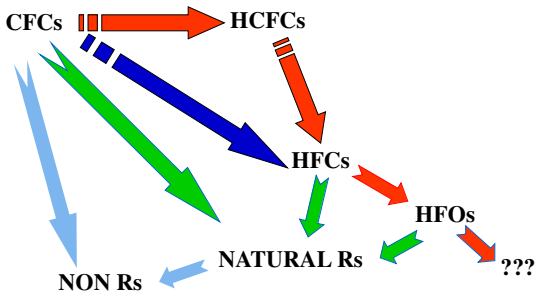
The third generation refrigerants sought to protect our ozone layer - the demise of CFCs followed by HCFCs

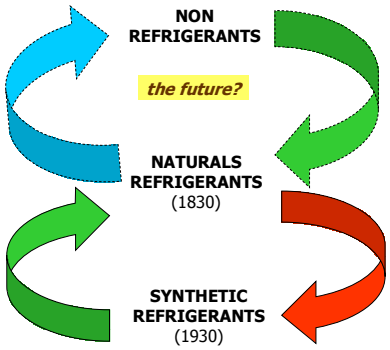
Today's fourth generation seeks to arrest global warming - completing the circle back to the first generation refrigerants

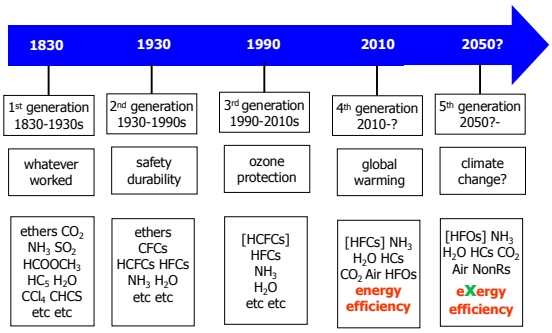


Refrigerant Progression

RECAP (1990):
Did we jump out of the frying pan into the fire?







Refrigerant Progression

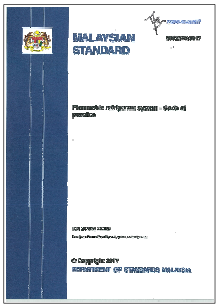
Natural Refrigerants

- Certainly European-led and it is heartening to note that the pace has been maintained if not increased since 1997
- Ammonia chillers for high-rise and commercial buildings are already established but .....
- HC airconditioners are prevalent in Scandinavian countries for the last decade
- HC domestic refrigerants are the norm in Europe; in Japan since 2005 .... and finally in Malaysia in 2017!!

MS on Flammable Refrigerant System

The need for this MS 2678 was initiated by Bomba .....

.... more than 15 years after the author first presented HC (flammable) refrigerant to the local industry in Jan 2000



Flammable Refrigerant System

MS 2678 consists of the following sections:

Section 1: Administration

Section 2: Definition and classification of flammable refrigerants

Section 3: Design, construction, testing, marking and documentation

Section 4: Installation site

Section 5: Operation, maintenance, repair and recovery

Flammable Refrigerant System

The purpose of MS 2678 is to promote the safe design, construction, disposal, installation, and operation of refrigerating systems and equipment using flammable refrigerants.

It is intended to minimize possible hazards to persons, property and the environment from refrigerating systems using flammable refrigerants.

These hazards are associated essentially with the physical and chemical characteristics of flammable refrigerants as well as the pressures and temperatures occurring in refrigeration cycles.

2.1 Flammable refrigerant

Flammable refrigerant - Refer to ISO 817 on class A2L, 2 and 3

ISO 817:2014 provides an unambiguous system for assigning designations to refrigerants. It also establishes a system for assigning a safety classification to refrigerants based on toxicity and flammability data, and provides a means of determining the refrigerant concentration limit.

Flammable Refrigerants

Refrigerant No.	Refri Prefix	Chemical Name	Formula	Safety Group
R32	HFC	methylene fluoride	CH_2F_2	A2L
R50	HC	methane	CH_4	A3
R142b	HCFC	chloro difluoroethane	CH_3CClF_2	A2
R143a	HFC	trifluoroethane	CH_3CHF_3	A2L
R152a	HFC	d fluoroethane	CH_3CHF_2	A2
R170	HC	ethane	CH_3CH_3	A3
R-E170		dimethyl ether	CH_3OCH_3	A3
R290	HC	propane	$CH_3CH_2CH_3$	A3
R600	HC	butane	$CH_3CH_2CH_2CH_3$	A3
R600a	HC	isobutane	$(CH_3)_2CHCH_3$	A3
R601	HC	pentane	$CH_3CH_2CH_2CH_2CH_3$	A3
R702		hydrogen	H_2	A3
R717		ammonia	NH_3	B2L

Flammable Refrigerants

Refrigerant No.	Refri Prefix	Chemical Name	Formula	Safety Group
R1150	HC	ethylene	$CH_2=CH_2$	A3
R1234yf	HFO	tetrafluoropropene	$CF_3CF=CH_2$	A2L
R1270	HC	propylene	$CH_3CH=CH_2$	A3
R403A		R290/22/218		A1/A2
R406A		R22/600a/142b		A2/A2
R411A, R411B, R412A, R413A, R415A, R415B, R418A, R419A, R429A, R430A, R431A, R432A, R433A, R433B, R433C, R435A, R436A, R436B, R437				

2.5 Refrigerant Charge Limit

Refrigerant charge limit – Refer ISO 5149-1:2014, Clause 6

6 Quantity of refrigerant per occupied space

6.1 The amount of a refrigerant charge that could enter into the occupied space shall be determined as follows.

- For occupied spaces, the refrigerant quantity shall not exceed the amounts specified in Tables A.1 and A.2

- The refrigerant quantity is the quantity that can be released in an occupied space, and shall be the largest charge of any single refrigerating system, unless otherwise specified in this International Standard.

6.2 Where IEC or ISO product standards exist for particular types of systems and where these product standards refer to refrigerant quantities, such quantities shall overrule the requirements of this part of ISO 5149.

Table 1 - Categories of occupancy

Categories	General characteristics	Examples[a]
General occupancy a	Rooms, parts of buildings, building where - sleeping facilities are provided, - people are restricted in their movement, - an uncontrolled number of people are present, or - to which any person has access without being personally acquainted with the necssary safety precautions	Hospitals, courts or prisons, theatres, supermarkets, schools,lecture halls, public transport termini, hotels, dwellings, and restaurants.
Supervised occupancy b	Rooms, parts of buildings, buildings where only a limited number of people can be assembled, some being necessarily acquainted with the general safety precautions of the establishment.	Business or professional offices, laboratories, places for general manufacturing, and where people work.
Authorized occupancy c	Rooms, parts of buildings, buildings where only authorized persons have access, who are acquainted with general and special safety precautions of the establishment and where manufacturing, processing, or storage of material or products take place.	Manufacturing facilities, e.g. for chemicals, food, beverage, ice, ice-cream, refineries, cold stores, dairies, abattoirs, and non-public areas in supermarkets.

[a] The list of examples in not exhaustive

3: Design, Construction, Testing, Marking ..

- Flammable refrigerants shall only be used in equipment or refrigerating system designed and constructed or retrofitted specifically for such application and the refrigerant used is clearly identified

3.2 Design and Construction

- **3.2.2 Marking and instruction**

When flammable refrigerants are used, the flammable refrigerant symbol, W021 (refer to Figure 1) shall be displayed appropriately according to ISO 7010.

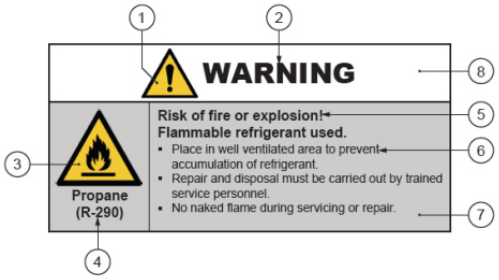
Figure 1. Flammable material symbol, W021

* Adopted from IEC 60335-2-40 – Clause 7.6

1. When a flammable refrigerant is used, a warning symbol W021 of ISO 7010 …. perpendicular height of the triangle containing the "Caution, risk of fire" symbol shall be at least 30 mm.
2. This marking should be present on all new equipment with all classes of flammable refrigerant

Annex B
(informative)

Advisory label for installer/service/supplier



3.3 Safety Control measures

- 3.3.1 Duties of installer/supplier/service personnel
  - to provide adequate documentation according to IEC 60335-2-40:2013; Annex HH
  - Advisory label to be affixed permanently
  - To be inspected and certified by an authorised/competent personnel
- 3.3.2 Duties of end users
  - Advised to engage trained service personnel…

4.2.13 Ventilation

- Section 4.2.13.2 – Ventilation in machinery rooms when occupied to be minimum of four air change
- Section 4.2.13.3 – Ventilation system requirement similar to ISO 5149-3:2014 – 5.14.1.2.

*Gas detector required for room with system charge exceeding the Practical Limit

Requirement on "Trained and Certified Operating Personnel"

- 5.1 General requirements

  Operation, maintenance, repairing and refrigerant recovery should be carried out by trained and certified personnel in the use of flammable refrigerants. Any personnel conducting an operation, servicing and maintenance on a system or associated parts of the equipment should be trained and certified. Personnel working on refrigerating systems with flammable refrigerants should be trained and certified to achieve competence in skills and safety aspects of flammable refrigerant handling.

Requirement on "Trained and Certified Operating Personnel" (cont'd)

- The general requirement of trained and certified personnel are indicated as below:

a) Knowledge of legislation, regulations and standards relating to flammable refrigerants;

b) Detailed knowledge of and skills in handling flammable refrigerants, personal protective equipment, refrigerant leakage prevention, handling of cylinders, charging, leak detection, recovery and disposal;

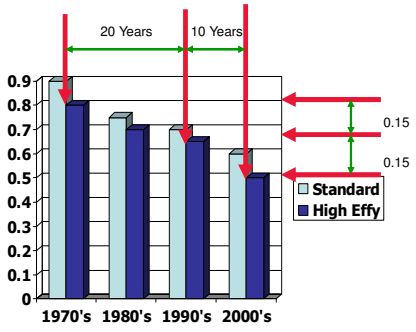
c) Able to understand and to apply in practice the requirements in this Malaysia Standard; and

d) Continuously undergo regular and further training to maintain this expertise

CONCLUDING REMINDER

- Why let 1% continue to dictate 99%?
- Cooling due to chillers accounts for only 15% of our local market
- Refrigerant Efficiency rather than Hardware Efficiency will continue to rule aka
- Energy Efficiency instead of Exergy Efficiency

Thermal Efficiency Progression
Chiller Efficiency : kWe/RT



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THANK YOU

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