Flammable Refrigerants – How to Apply Safely

Kevin Lee – M.AIRAH
Why the Need for Flammable Refrigerants?

• Climate Change
  o World wide move to phase down HFC’s
  o Introduction of the carbon tax in Australia in 2012
  o Drive to low GWP solutions

• The past was easy
  o Refrigerants were non toxic, non flammable
  o But, they had high Ozone Depleting Potential (ODP) and Global Warming Potential (GWP)

• The future
  o No single solution
  o A ‘suite’ of refrigerant solutions – CO2, NH3, HC, HFO’s
  o They will all have there place

Including Flammables
Some Characteristics of Note

- Lower GWP substances are generally less chemically stable – this is good!
- Consequence is they are more flammable and/or toxic than high GWP substances.

<table>
<thead>
<tr>
<th></th>
<th>R290</th>
<th>R1234yf</th>
<th>R152a</th>
<th>R32</th>
<th>R134a</th>
<th>R125</th>
<th>R12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life in Air (yr)</td>
<td>11 days</td>
<td>1.4</td>
<td>4.9</td>
<td>14</td>
<td>29</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>GWP (100yr)</td>
<td>&lt;4</td>
<td>4</td>
<td>124</td>
<td>675</td>
<td>1430</td>
<td>3500</td>
<td>10900</td>
</tr>
<tr>
<td>HoC (Mj/kg)</td>
<td>46.3</td>
<td>10.7</td>
<td>16.5</td>
<td>9.4</td>
<td>6.6</td>
<td>4.0</td>
<td>?</td>
</tr>
</tbody>
</table>

(HoC = Heat of Combustion)

Source: modified from slide 5 ‘OEWGCCAC Seminar June 2013 kataoka V2’
Flammable Refrigerant Background

- According to Greenpeace over 700 million domestic fridges worldwide in last 20 years using ‘Greenfreeze’ – R600.
- In Australia
  - > 400,000 domestic refrigerators on HC’s – manufactured by Electrolux at Orange
  - > 35,000 HC Ice cream cabinets – Streets, Walls
  - HC display cabinets in Supermarkets - Aldi
  - Large Chillers on Hydrocarbons
  - R32 mini splits launched in Oct 2013 – Fujitsu, Daikin, Electrolux

So why is it, that the use of flammable refrigerants is not more widespread?
We Must Ensure Refrigerant Safety as We are Reducing GWP

- Minimise GWP of refrigerants.
- Minimise risk of ignition – safe electrics and location of systems.
- Minimise consequence of ignition - acceptable flammability depends on charge amount and location of system.

Source: modified from slide 6 ‘OEWGCCAC Seminar June 2013 kataoka V2’
What’s Europe Doing?

• Denmark as an example
  o One of the most environmentally progressive nations in the world has banned HFC for systems below 150 grams and above 10 kgs.

• Why that particular range?

• <150 grams
  o Well established standards.
  o OE manufacture, good design, fully sealed systems.
  o Large & fast growing installed base of OEM equipment.

• > 10 kgs
  o Size of system justifies extra engineering controls to ensure safety.
  o Secondary systems to contain flammable refrigerant in plant room or in open air.

‘Conversions’ seldom done, except large chillers
Fire safety, at its most basic, is the principle of keeping fuel sources and ignition sources separate.
Risks are minimised and safety ensured through:

• Reduction in fuel/air mixture through
  o Strict charge limits to avoid reaching LFL
  o Minimise risk of leaks – e.g. no mechanical joints
  o Minimise risk of pooling – e.g. ventilation

• Remove sources of Ignition and heat
  o Application & location requirements
  o Strict construction and hazardous area requirements
    ▪ Electrical contactors, motors, controls
  o Signage and access requirements

• Training

What happens if you don’t follow the above requirements?
Tamahere
(Waikato, New Zealand)
Tamahere

• Date of incident 5\textsuperscript{th} April 2008.

• Icepak cold store with 2 off R22 DX systems converted to Hydrocarbon with charges of \(~220 & \sim 175\) kg each.

• Explosion occurred during fire brigade attendance for a smoke alarm.

• Resulting in death of one fire-fighter, 7 others injured, two of them critically.
Tamahere

- Fire-fighters entered plant room in presence of a white smoke cloud which was odourless.
- Source of leak located at a fitting on top of compressor.
- Scenario is that the vapour cloud was pulled into the main switchboard cabinet at the base by the ventilation fan and the air mixture was expelled at the top.
- Relay contactor closed or opened causing spark and subsequent explosion.
Tamahere

• Plant rooms contained other ignition sources
  o Switchboard had inbuilt fans
  o Gas detectors and control panels not rated for hazardous areas
  o Extraction fans not rated for hazardous area.
• 5 months prior, one of the racks lost 80kgs of HC,
  o Gas detector damaged and not replaced for 2 weeks.
  o No investigation as to cause and remedies.
Date of incident – 5 July 1999

Under-bar Fridge/Freezer cabinet with a Kirby condensing unit mounted in an enclosure at right hand end.

Explosion during charging of the unit with Care 50 – blend of Propane, Isobutane and ethane.

Mechanic severely injured, Café owner also injured. Both hospitalised.
Café Grove

• 10 year old leaky system
  o Jan 99 – ice in TX valve, valve replaced and ‘thaw zone’ added to system.
  o Feb 99 – new compressor fitted and system re-gassed with R22.
  o Apr 99 – system still playing up, leaks repaired and re-gassed with Care 50.
  o 9:30am, 5th July – system appeared low on gas, leak found and repaired.
  o 10:10am, 5th July - re-gassing with Care 50 when tube burst on condenser coil.

Panic! - Mechanic pulled 3 pin plug out of wall socket and escaped gas exploded.
Do you think this system was suitable for flammable refrigerant?
What Do They Have in Common?

- Both ‘retrofits’ using so called ‘drop-in’ refrigerants
- Both old leaky systems
- Charge limits exceeded
- Ignition sources not addressed
  - Electrical systems not suitable
- Standards and Regulations not adhered to
- Risk assessments not carried out
- Inadequate training
- Inadequate signage

How do you ensure that you don’t fall into these traps?
Use the Flammable Refrigerants Safety Guide
Safety Guide Contents

1. Scope and application
2. Legislative framework
3. Classification and application of flammable refrigerants
4. Safety requirements for design and manufacture
5. Risk assessment, controls and detection systems
6. Service and maintenance
7. Emergency planning
8. Personal protection and safety information
9. Marking and labelling
10. Training
11. Storage
12. Transport
13. Compliance audit tool

Appendix A – Checklists
Appendix B – Self assessment tools
Appendix C – Example fire service notification template
Appendix D – References and resources
1. Scope and Application

- **Scope**
  - Provides guidance on managing safety risks associated with the design, manufacture, installation, commissioning, service, use, decommission of equipment.
  - Also covers the storage and transport of flammable refrigerant.

- **Application**
  - Applies to all stationary refrigerating systems of all sizes including air conditioners.
  - Applies to all A2 or A3 refrigerants or any other refrigerant that meets the criteria to be classified as an A2 or A3.
  - Does not cover automotive A/C or mobile applications or Ammonia systems.
1. Scope and Application

- Converting Systems (section 1.3)
  - Conversion is the term used to change a system from one refrigerant to another where the new refrigerant has a higher flammability or toxicity classification.
    - Example an R22 (A1) air conditioner is converted to R290 (A3).

- Should not be undertaken unless you have:
  - Competence in the design of refrigerating equipment.
  - Detailed knowledge of the applicable electrical safety standards.
  - Competent to recognise when additional engineering controls are required and how to implement.
1. Scope and Application

Converting Systems (section 1.3)

- If you modify an electrical appliance then you take the responsibility for the electrical safety of the appliance.
  - Electrical safety regulators (section 2.4) would consider that you have created a new electrical appliance.
  - In this case you would have to be registered as a ‘responsible supplier’ and depending on the risk level of the appliance you would have to provide evidence of compliance.
  - i.e. You as the modifier have become the equipment manufacturer.

Beware of the term ‘Drop-in’ replacement

- This should only be used when replacing a refrigerant of one safety classification with another of the same safety classification.
- Example R22 (A1) with R438 (MO99) or R407C. Both of these replacements are A1
Your responsibilities

• Primary duty of care (section 1.5)
  - You must ensure so far is reasonably possible, that workers and other people are not exposed to health and safety risks arising from the business or undertaking.
  - Duty requires management of risks or elimination of risks.
  - Applies to all workforce – designers, manufacturers, suppliers, officers and workers.
2. Legislative Framework

Acts and regulations (sections 2.1 thru 2.5)

- An Act sets out general duties of care - WHS act.
- The Act enables regulations to be made in relation to safety.
- State or Territory based and do vary, but all have the same principles.
- Electrical safety regulations
  - Prescribes minimum standards of safety for electrical equipment.
  - AS/NZS3820 called up and defines the essential requirements for low voltage electrical equipment.
  - Compliance to AS/NZS3820 is mandatory and can be demonstrated by compliance to the relevant product standard (listed in Appendix B of AS/NZS3820).
- Codes of practice
  - Applies to anyone who has a duty of care.
  - Following an approved code would achieve compliance with the WHS act.
  - Codes are admissible in court proceedings under the WHS act and regulations.
2. Legislative Framework

Queensland regulations for hydrocarbons (section 2.3)

- Refrigerating devices using hydrocarbons is a Type B gas device and is required to be approved before it is sold, installed or used.

- Anyone installing, removing, altering, servicing a refrigerating system on hydrocarbons must hold a gas work licence.

- Details on requirements can be found at [www.mines.industry.qld.gov.au](http://www.mines.industry.qld.gov.au)
2. Legislative Framework

Australian Standards (section 2.6)

• Refrigeration Standards
  o AS/NZS 1677.1 – Refrigeration systems, Part 1 – Refrigerant Classification.
  o AS/NZS 1677.2 – Refrigeration systems, Part 2 - Safety requirements.

• Handling and Storage

• Product safety standards (listed in AS3820 Appendix B)
  o AS/NZS 60335 series
    ▪ Part 1  Household and Similar Electrical Appliances – Safety – General requirements
    ▪ Part 2 standards (over 100 off) detail particular requirements for a specific product
    ▪ Example – AS/NZS 60335-2-40 – Particular requirements for electrical heat pumps, air conditioners and dehumidifiers
  o Usually used by designers and manufacturers
  o Take precedence over a general standard – i.e. AS/NZS 1677.2
2. Legislative Framework

Australian Standards (section 2.6)

• Pressure Equipment standards
  o AS 4343 – Pressure equipment – Hazard levels
    ** If you change from an A1 to A3 refrigerant you may increase the hazard level of the pressure vessel(s), piping etc. and they may no longer be compliant

• Electrical installation and related safety standards
  o AS 1482 – Electrical equipment for explosive atmospheres
  o AS/NZS 3000 – Electrical installations
  o AS/NZS 60079 series – Explosive atmospheres
    ** Covers classification of areas into hazard zones and the selection and installation of electrical equipment. Covered in section 4.4
3. Classification and Application of Flammable Refrigerants

Definitions used to classify Refrigerants

from AS/NZS 1677.1 & ASHRAE 34

• **LFL** – lower flammability limit or **LEL** – lower explosive limit
  o Minimum concentration of the refrigerant that is capable of propagating a flame through a homogeneous mixture of the refrigerant and air at 21.0°C and 101.3 kPa.

• **HoC** – Heat of Combustion
  o Heat evolved from a specified reaction of a substance with oxygen, expressed in energy per unit mass (kJ/kg).

• **LC50** – lethal concentration expected to cause death of 50% of a rat population when exposed to a substance in air for an exposure of 4 hours.

• **BV** – burning velocity (new!)
  o Maximum velocity (cm/s) at which a laminar flame propagates in a normal direction relative to the unburned gas ahead of it.
  o **Note** – a flammable gas mixture moving at a velocity above its BV cannot be ignited.
3. Classification and Application of Flammable Refrigerants

Refrigerant classification - Flammability

- **Class 1 (No Flame Propagation)**
  - Refrigerant that do not exhibit flame propagation in air at 60°C and 101.3 kPa

- **Class 2L (mild flammability) (new, not included in Guide)**
  - Additional condition of maximum burning velocity (BV) of < 10 cm/s

- **Class 2 (Lower Flammability)**
  - Exhibit flame propagation when tested at 60°C and 101.3 kPa
  - Have a LFL > 3.5% by volume
  - Have a heat of combustion < 19,000 kJ/kg

- **Class 3 (Higher Flammability)**
  - Exhibit flame propagation when tested at 60°C and 101.3 kPa
  - Have a LFL ≤ 3.5% by volume, or
  - Have a heat of combustion ≥ 19,000 kJ/kg
3. Classification and Application of Flammable Refrigerants

Refrigerant classification – Toxicity

- Group A – Non Toxic - LC50 > 10,000 parts per million
- Group B – Toxic - LC50 < 10,000 parts per million

Note:
- Toxicity classification is only for the refrigerant in its pure form.
- All synthetic refrigerants give off toxic fumes when burnt or exposed to excessive heat.
- Do not use a brazing torch in the presence of any refrigerants and ensure you have good ventilation.
Combined Refrigerant Classification

- **Group A1**
  - Non Toxic
  - Non flammable
  - Examples – R22, R410A, R134a

- **Group A2**
  - Non Toxic
  - Lower flammability
  - Examples R32, R152

- **Group A3**
  - Non Toxic
  - Higher flammability
  - Examples – R290, R600

- **Group B2** *(not covered by Safety Guide)*
  - Toxic
  - Lower flammability
  - Example – R717 (Ammonia)
3. Classification and Application of Flammable Refrigerants

Group A2L – some background

- A new safety classification that is expected to be introduced in ISO 5149-2014 (not yet published)
- Was introduced into ASHRAE 34 in 2010
- Expected to be adopted in Australia when ISO 5149-2014 replaces AS/NZS 1677.2.1998
- Currently R32 is treated as an A2, in the future it will be treated as A2L
  - Relaxed charge limits and electrical requirements
- Similarly, Ammonia which is currently B2 will become B2L
4.2 Electrical appliance charge limitations

- Summarised in Table 4.1
- Supersede those detailed in AS/NZS 1677
- Typically 150 grams maximum for self contained appliances with 3 pin plugs
- No restrictions on where they can be installed or number in a room (up to 5 off)
- A/C units – up to 1 kg
4. Safety Requirements for Design and Manufacture

4.3 Charge limits based on flammability classification

• Allowable charge
  o Based on room volume (in m³) and the ‘practical limit’
    (20% of the LEL and in kg/m³)
  o Practical limits listed in Table 4.2

• Maximum Charge
  o Absolute upper limit that the allowable charge can reach for the applicable ‘occupancy class’

Note:
• When determining charge limitations use ‘net’ room volume.
• For A/C units that can be zoned – use smallest volume
4.4 Hazardous areas – explosive gas atmosphere

- If a flammable gas leaked to atmosphere can form a concentration that can exceed 5% of the LEL then that work area must be deemed a hazardous area under WHS regulations.

- The hazardous area must be evaluated for zoning under AS/NZS 60079.10.1
  - Zone 0 – explosive gas atmosphere present continuously or long periods
  - Zone 1 – explosive gas likely to occur in normal operation occasionally
  - Zone 2 – explosive gas not likely to occur in normal operation, but if it does occur, it is for short periods only

- If an installation results in a hazardous area classification then additional standards apply – AS 1482 and AS/NZS 60079.14
4. Safety Requirements for Design and Manufacture

4.5 Allowable charge of flammable refrigerant

Pooling Risk

- Most flammable refrigerants are heavier than air
- Leaks from a low height have little mixing or dilution
- Ventilation can play a key role
- Example is CO2 – similar density to Propane (R290)
4. Safety Requirements for Design and Manufacture

4.5 Allowable charge of flammable refrigerant

Pooling Risk

• Special concern for installations occupied by humans where they sleep or are incapacitated

• Leaked gas cannot be smelt

• Allowable charge is based on a formula that takes installation height into consideration – dilution effect

• Refer Anexx GG of AS/NZS 60335.2.40
4. Safety Requirements for Design and Manufacture

4.6 Maximum charge limits based on occupancy classification

Occupancy Category

- General occupancy I – where people can sleep, restricted in movement, uncontrolled number
  - Hospitals, supermarkets, schools, dwellings

- Supervised occupancy II – limited number of people, some being acquainted with safety procedures
  - Business or professional offices, laboratories

- Authorised occupancy III – rooms, parts of building where only authorised persons have access
  - Manufacturing facilities, cold stores, non public areas in supermarkets
4. Safety Requirements for Design

**Table 4.4 AS/NZS 1677.2 and AS/NZS60335.2.40 – Maximum charge limits for A3 refrigerants**

<table>
<thead>
<tr>
<th>Occupancy category</th>
<th>Location classification</th>
<th>Direct (1)</th>
<th>Indirect (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct (1)</td>
<td>Indirect (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Refrigeration system or refrigerant containing parts located in occupied space</td>
<td>Compressors and pressure vessels in machinery room or open-air</td>
<td>All refrigerant containing parts located in a machinery room or open-air</td>
</tr>
<tr>
<td>I</td>
<td>Human comfort</td>
<td>According to Annex GG of AS/NZS 60335.2.40</td>
<td>5kg Clause 2.6.2(b)</td>
</tr>
<tr>
<td></td>
<td>Other systems (a)</td>
<td>1.5kg Clause 2.6.2(a)</td>
<td>1.5kg Clause 2.6.2(b)</td>
</tr>
<tr>
<td>II</td>
<td>Human comfort</td>
<td>According to Annex GG of AS/NZS 60335.2.40</td>
<td>10kg Clause 2.6.3(a)</td>
</tr>
<tr>
<td></td>
<td>Other systems (a)</td>
<td>2.5kg Clause 2.6.3(a)</td>
<td>10kg Clause 2.6.3(b)</td>
</tr>
<tr>
<td>III</td>
<td>Human comfort</td>
<td>According to Annex GG of AS/NZS 60335.2.40</td>
<td>Unrestricted Clause 2.6.4 (c)(i)</td>
</tr>
<tr>
<td></td>
<td>Other systems (a)</td>
<td>10kg Clause 2.6.4(a)(i)</td>
<td>25kg Clause 2.6.4(b)(i)</td>
</tr>
</tbody>
</table>

Charge increases as refrigerant is more remote – less risk

Charge increases as persons more qualified and/or mobile
4.7 Sources of ignition

4.7.2 Hot surfaces
   • condensate tray or defrost heaters

4.7.3 Electrical sources of ignition
   • Contactors, HP/LP switches

4.7.4 Naked flame ignition sources
   • Gas stoves, cooktops, gas water heaters, wood fires

4.7.5 Static electricity and lightning
   • Extra care on earthing metal structures

4.7.6 Mechanical equipment
   • Frictional sparking etc. – angles grinders!

Guidance on these factors in AS/NZS 60079 standards
4. Safety Requirements for Design and Manufacture

4.8 System jointing and construction
• Avoid mechanical joints in occupied space or where leaked refrigerant could pool

4.9 Pressure equipment design and plant registration
• Depending on Hazard level category (A, B, C or D) either design and/or plant registration is required.
• ** A conversion from A1 to A2 or A3 may change Hazard level and a new level of registration

4.10 Protection against excess pressure
• Consider where pressure relief valves are located and where the discharge is directed.

4.11 Fire service notification
• Notify local fire service for systems charge with more than 5 kg.
• Use template in Appendix C
5. Risk Assessment

- Determine those risks that need to be controlled
- Assist in making decisions about the order in which risks should be controlled
- If the risk cannot be eliminated or controlled, should the installation go ahead?
- Often overlooked in the service or maintenance situation

Warning: Most accidents occur during service or maintenance. Do not be complacent about the risks
6. Service and Maintenance

6.3 Pre-service safety
- Risk assessment
- Do you know exactly what refrigerant is in the system – if unsure treat as flammable!
- Minimise risk of ignition

6.4 Temporary flammable zone
- Establish the area required and display appropriate signage.
- Remove sources of ignition

6.5 Refrigerant recovery
- Do not recover hydrocarbons into HFC reclaim cylinders
- Is the recovery equipment suitable for flammable gases
- For R32 use dedicated R32 reclaim cylinders

Note – the standard HFC/HCFC reclaim cylinders do not have the correct pressure rating or flammable gas labelling.
7. Emergency Planning

• Under WHS legislation you must prepare an emergency plan

• Emergency plan must provide
  
  o Emergency procedures
  
  o Evacuation procedures
  
  o Notifying emergency services
  
  o Medical treatment and assistance

• Plan needs to be readily accessible and/or on display in the workplace

• Workers need to be trained in emergency procedures
9. Marking and Labelling

9.2 Marking and labelling of systems and units
   • All refrigeration and A/C units containing flammable refrigerants must be labeled with a “Class label”
   • Size of Class label is dependent on charge size
   • Name plate or serial plate must also identify refrigerant by ‘R’ number and include Class label

9.3 Marking and labelling of pipework
   • Interconnecting pipework should be marked with a Class label every 2 metres where pipework is visible – includes ceiling spaces or any voids

10. Training

• If you are working with flammable refrigerants, designing systems for them etc., then under WHS regulations you must be a ‘competent person’

• A ‘competent person’ must have the acquired knowledge and skills to carry out the task.

• The Safety Guide in section 10 details the appropriate courses, qualifications etc. for the various tasks/job functions.

• Note: R32 TAFE course material is currently being developed. If you wish to install an R32 minisplit, the manufacturers, Fujistsu, Daikin etc. are conducting training courses for their equipment.
12. Transport

- ADG code for transport of Dangerous Goods by Road and Rail.
- For transport, gas cylinders must be marked
  - Proper shipping name
  - United Nation number – ex – R32 is UN3252
  - A Class label
  - Note: Treated as DG whether full or empty

Warning: Do not stow gas cylinders inside a van that is unventilated. Stow in a cabinet that is vented externally only and not into the vehicle.
Appendix A - Checklists

- 4 checklists provided that step through the issues that need to be addressed to install or convert a system.
  - A1 High-wall spilt-system checklist
  - A2 Cool room refrigeration system
  - A3 Plant room-based refrigeration system
  - A4 Checklist for emergency plans

- Step by step guide that refers back to each section in the Safety Guide.
Flammable Refrigerants SAFETY GUIDE

A free download from the AIRAH website

www.airah.org.au
In Closing

Flammable refrigerants

• Are not a simple ‘Drop-In’ replacement for non-flammable refrigerants.

• If used to replace a non flammable refrigerant you must treat it as a “whole system conversion”

Follow the Guide!
Thank You!

Kevin Lee, M.AIRAH
Any Questions?

Have you any questions about this presentation or about the content of the Flammable Refrigerant Safety Guide?
We Would Love to Hear From You

Please help us evaluate what we do.

Complete the evaluation form and let us know what YOU think.

A FREE pen for every evaluation completed!