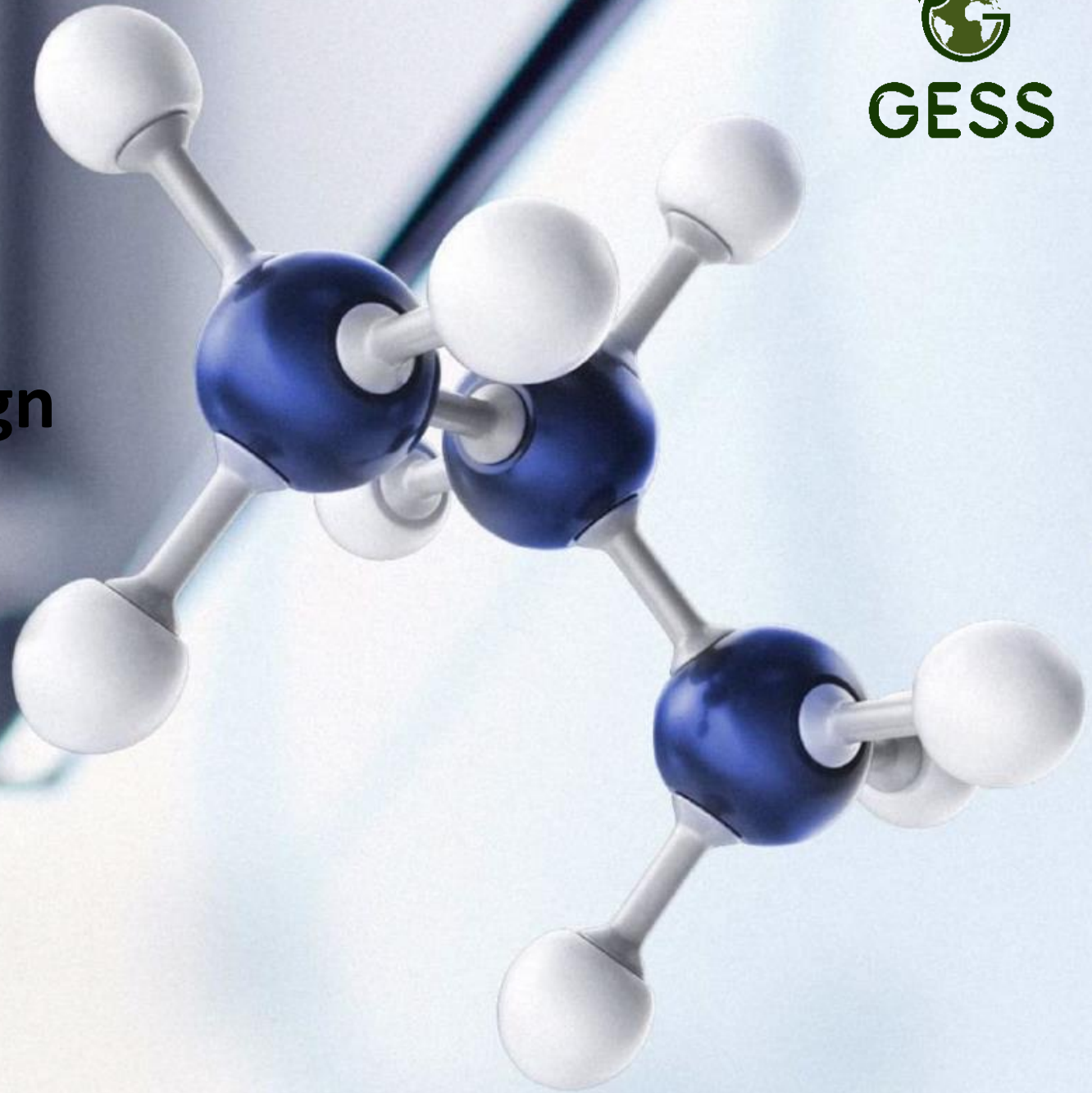


# Hydrocarbons – R290 Journey and success

## Challenges Involved in Design of the R290 System

et  
by GESS International FZC LLC

JUNE 24<sup>th</sup> 2021



# R 290 Experience



- Hydrofluorocarbons (HFCs), the human-made chemicals inside of air-conditioners used to cool the air, are super greenhouse gases, up to 3,000 times more potent than CO<sub>2</sub> at trapping heat in the atmosphere. What it comes down to is this: By cooling ourselves off, we risk cooking ourselves to death. -- Source- Rolling Stone News – June 22,20221
- The environmentally harmful effect of HFO refrigerants due to the trifluoroacetic acid that is formed as one of their atmospheric decay products will very likely lead to banning HFO refrigerants in a future European F-gas regulation. Ultimately, only natural refrigerants will be approved for new installations.
- At least two enterprises have development of ACs using HC-290 – Gree in China and Godrej in India.

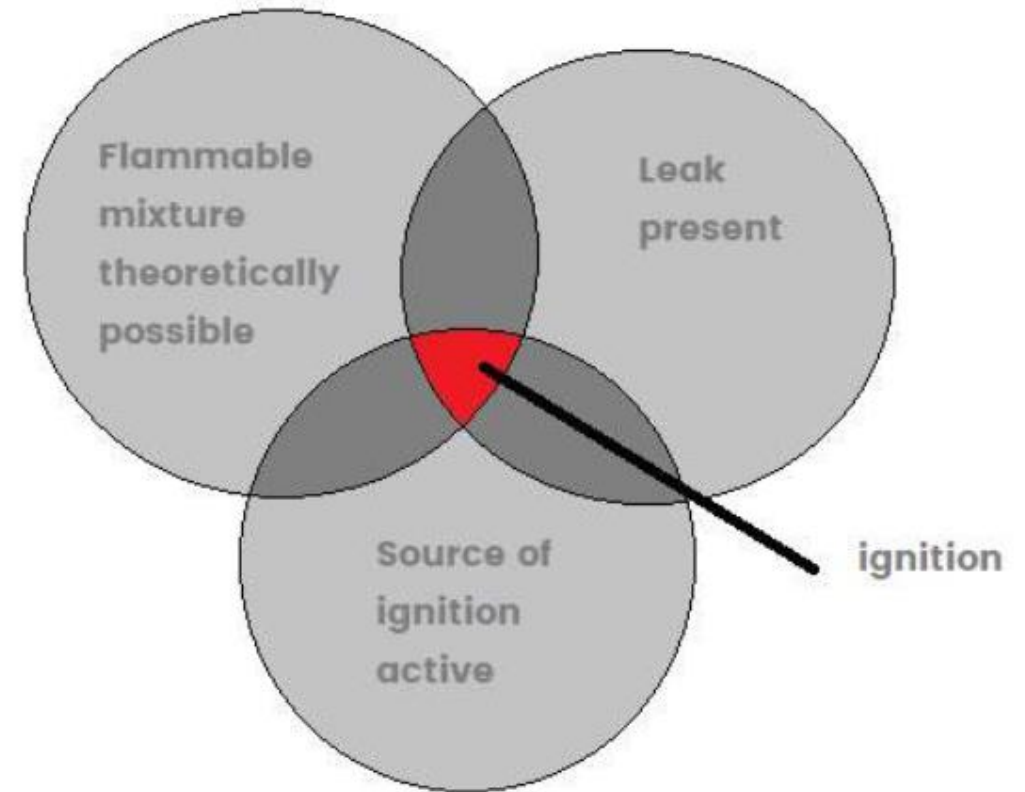
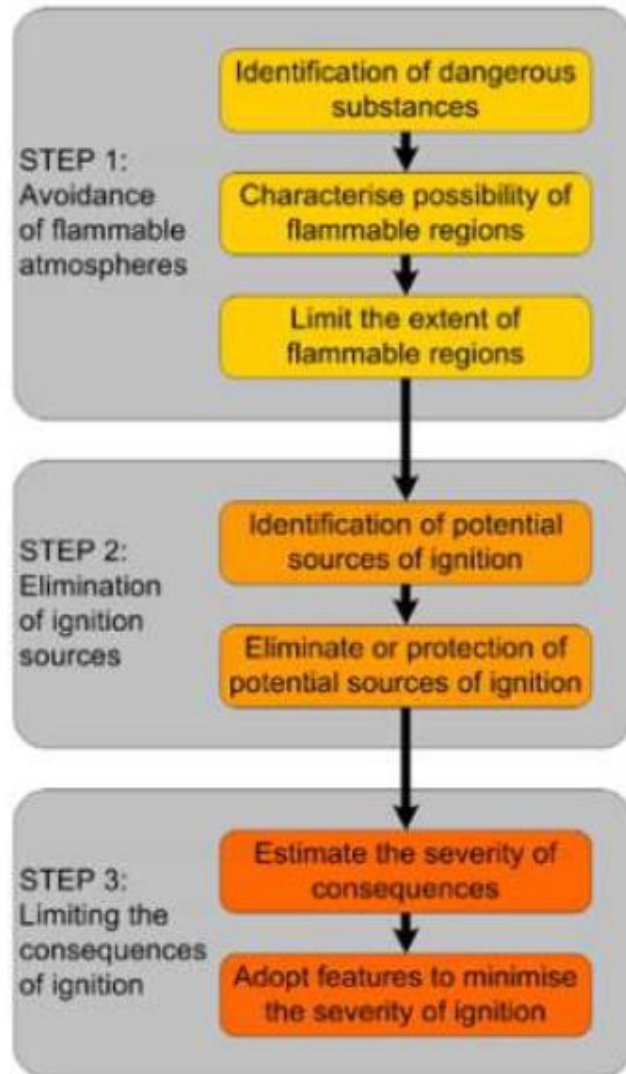
*In India ,Godrej participated in the GLZ program under German Ministry of environment to adopt R290 to reduce green house emission*

# Hydrocarbon Refrigerant Safety

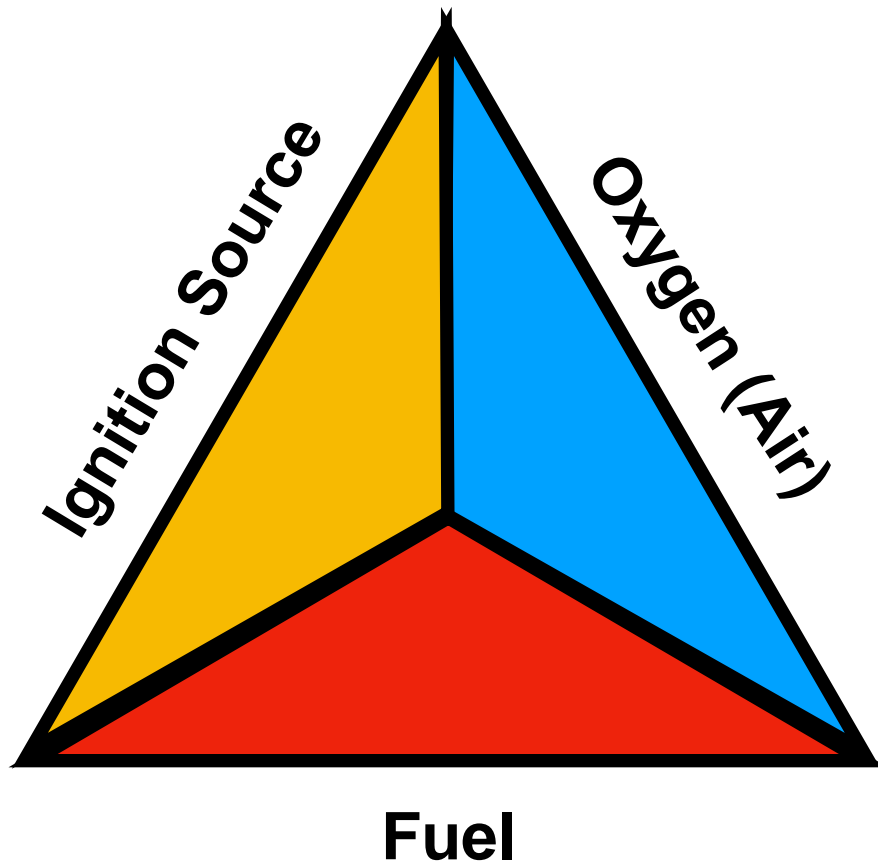


- **Hydrocarbon Refrigerants are Flammable**
- Hydrocarbons are used Daily and Safely throughout the world today for **Cooking, Heating, Powering Vehicles, and as Aerosol Propellants for Fly Spray, Deodorants, Whipped Cream and Cooking Sprays etc..**
- The Application of Flammable HC Refrigerants can be done safely as with any other type of refrigerant.
- All Refrigeration & Air Conditioning Systems Using Chemical Refrigerants Become Flammable due to the oil mixing with the refrigerant as it travels around the system.
- Most Chemical Refrigerants produce **toxic by-products and poisons gases** when they are burnt or over heated
- Hydrocarbons **DO NOT** spontaneously combust on contact with air

# R290 Hazard Analysis



# The Flammability Triangle

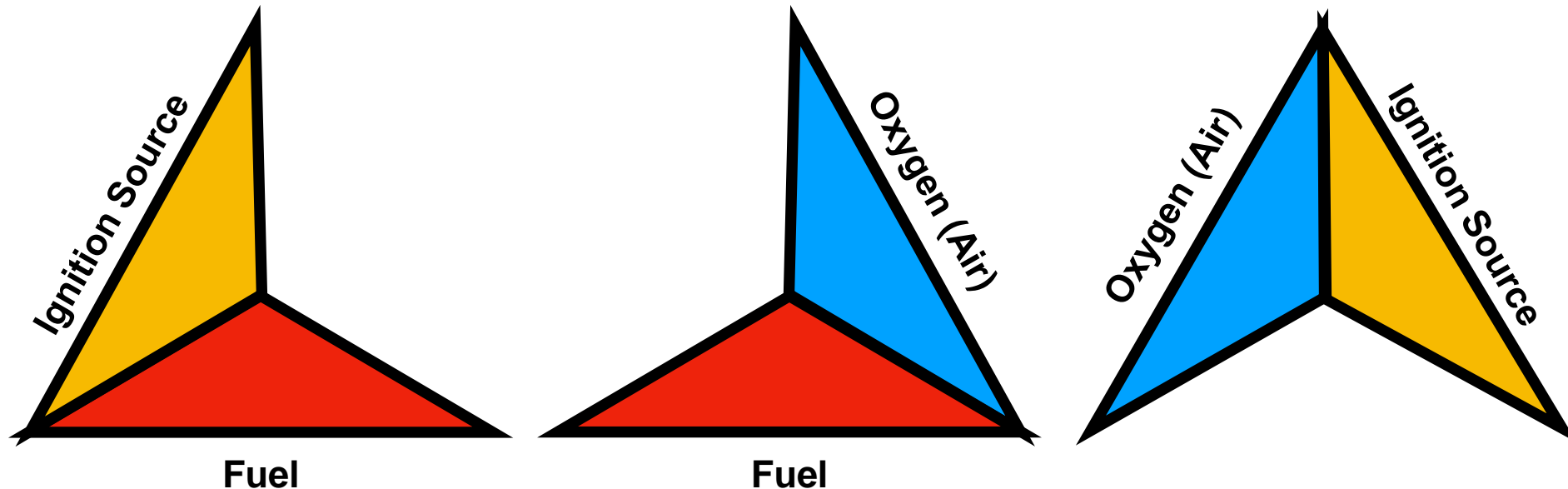


- Here we have **all 3 elements** in place to have the potential for a fire or ignition
- You **MUST** have **ALL THREE** for any risk to occur

# Flammability Triangle

## Continued

- Here We Have Only 2 of the 3 Elements Needed to Cause a Fire or Ignition
- Remove Any ONE of the 3 Elements, **An Incident CANNOT Occur.**





# Where do we have daily uses of Flammable Hydrocarbons



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**Average LNG Carrier**  
**73,440,000Kgs Of Hydrocarbon**



**Airbus A380**  
**320,000 Liters Of Hydrocarbon**



**Autogas Refuelling Station**  
**20,000Kgs of Hydrocarbon**



**Home Gas Supply**  
**2 x 45Kgs Hydrocarbon**

# Daily Uses Of Flammable Hydrocarbons Cont.



**Autogas Tank**  
**50kgs Hydrocarbon**



**BBQ Cooking Gas**  
**4.5Kg - 15Kg Hydrocarbon**



**12000Btu Wall Mouth AC**  
**0.3Kg Hydrocarbon**



**Fly Spray**  
**0.5Kg Hydrocarbon**



**Home Refrigerator**  
**0.05Kg Hydrocarbon**



# Daily Uses Of Flammable Hydrocarbons cont.



**Piped Gas Supply**  
**\*Unlimited Hydrocarbon\***

## Uses

**Cooking**



**Heating**



**Hot Water**



<b><u>DAILY USE</u></b>	<b><u>Hydrocarbon QTY</u></b>
LNG CARRIER	74,440,000Kgs
PLANE	320,000Kgs
REFUELLING STATION	20,000 - 40,000Kgs
HOME GAS BOTTLES	45 - 320Kgs
VEHICLE TANK	50Kgs
BBQ	4.5 - 15Kgs
FLY SPRAY	0.50Kgs
AIR CONDITIONER	0.30Kgs
REFRIGERATOR	0.05Kgs



# So if I can use Flammable Hydrocarbons Safely For?



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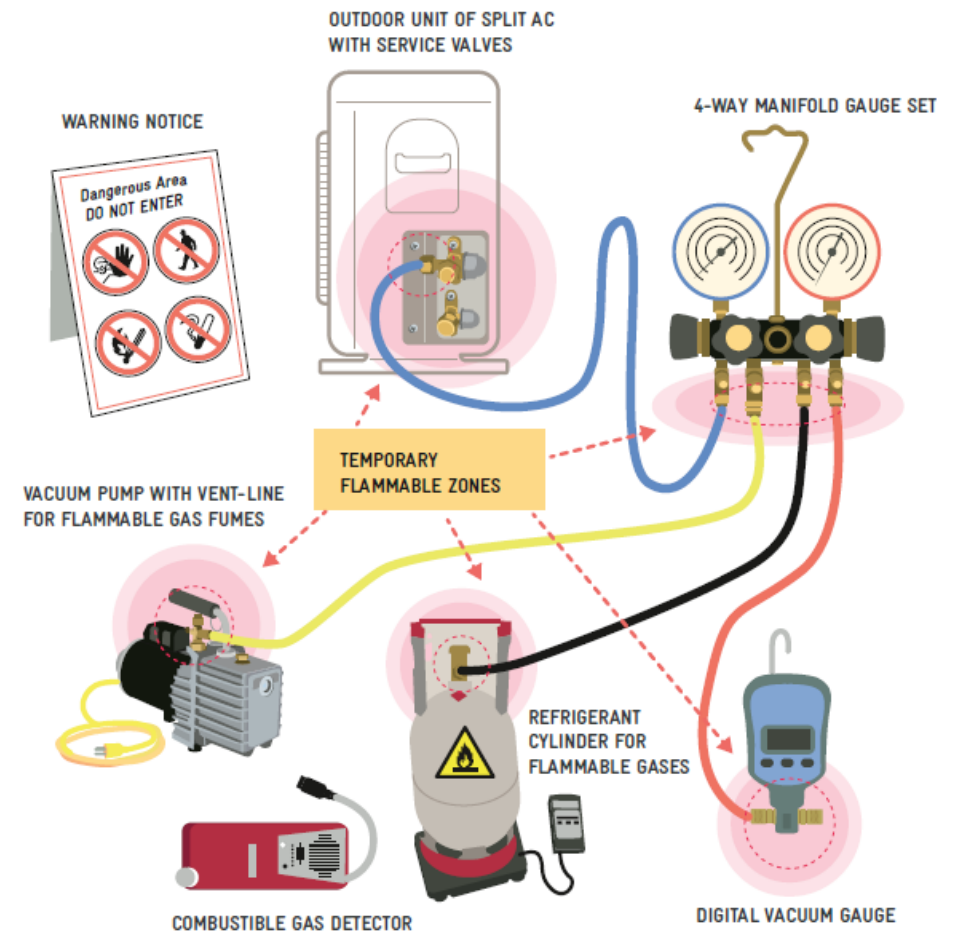
- Air Transport
- Vehicle Transport
- Cooking My Food
- Deodorant and Fly Spray Cans
- Heating My Water
- Heating My Home



**So Why Can't I Use Hydrocarbons for Cooling My Home?**

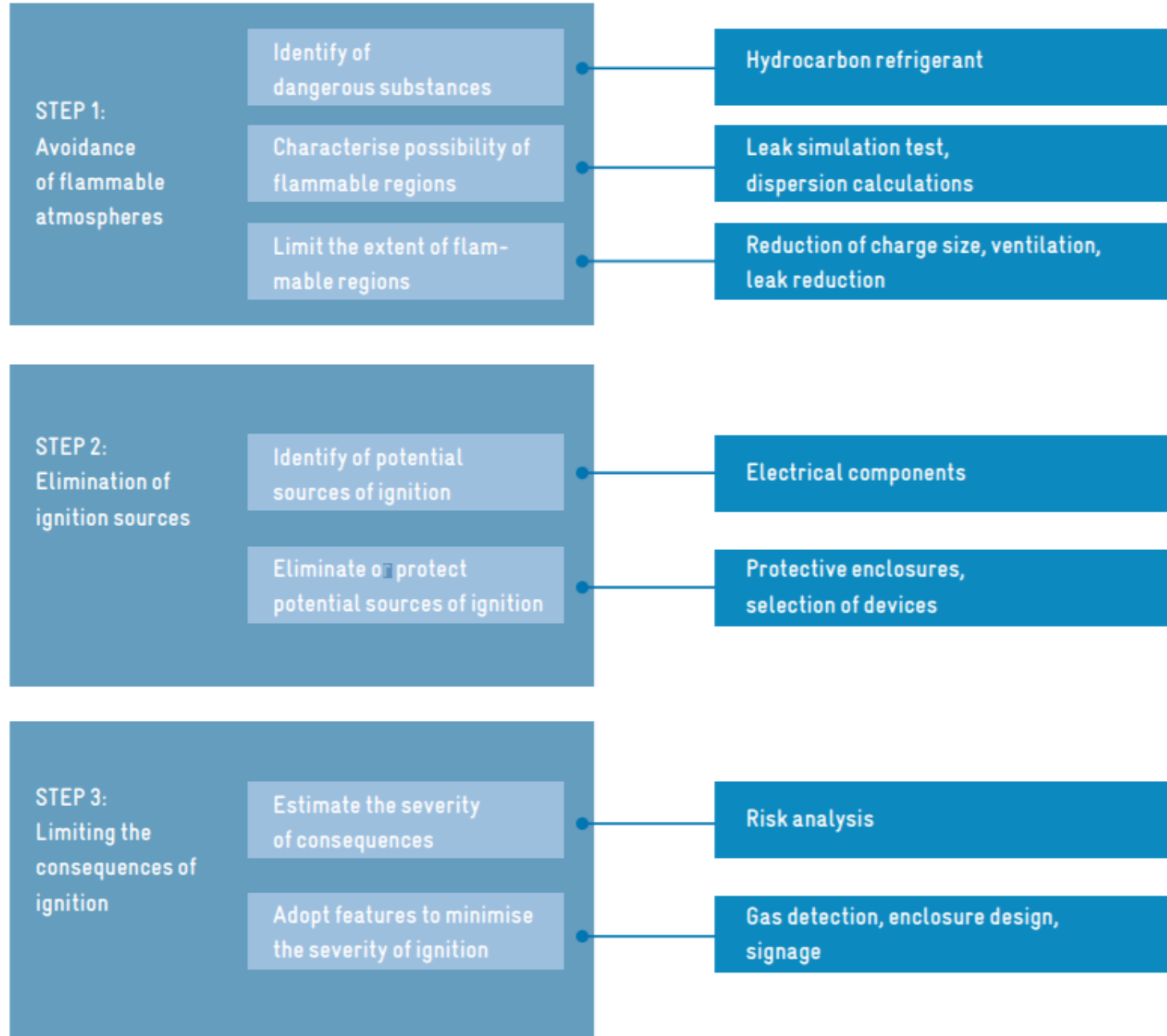
## Following design consideration are critical

- Charge Size
- Critical component design and development.
  - Compressor.
  - Electronic controller.
  - EEV ( Electronic Expansion Valve)
  - Motors.
  - Wire and Harness.
  - Condenser/ Evaporator
  - Sensors/ Alarms
  - Metal Shield, Cases.
- Software Development
  - Algorithm
  - Protection.
  - IoT warning messages, Alarms
- Testing and Validation Instruments.
  - Manifold Gauges.
  - Gas detection System
  - Vacuum Pump





# SAFE DESIGN AND CONSTRUCTION



# Current requirement for Safety using flammable refrigerant

Category	IEC 60335-2-40
	EN 60335-2-40
Scope	Factory-made whole ACs, heat pumps, dehumidifiers, and partial units
Limits on refrigerant charge amount	Approx. 1 kg of hydrocarbon in a direct system inside (depending on room size) and 5 kg outside or special enclosure
Marking	Requirement of flammability warning symbols
Strength pressure	Specification of pressure tests for systems and components (where applicable)
Electrical equipment	Specification of design, construction, and test requirements
Sources of ignition	Description of what to consider and how to avoid a potential source of ignition, including a test method option
Information & instructions	Details concerning the installation, use, service, maintenance, and disposal of the equipment so that users, operators, and technicians are aware of how to handle flammability hazards
System tightness	Systems generally have to be constructed as "sealed" or "hermetically sealed" systems if they are to use flammable refrigerants indoors (e.g. no or limited number of reusable mechanical connections or fittings)
Pressure limiting/ relief devices	The need for additional devices to limit or relieve excess pressure may apply to smaller systems if flammable refrigerants are used
Secondary/ indirect systems	Additional components for secondary or indirect refrigerant circuits (such as those using water or brine) are required to vent a leak that has occurred from the evaporator into the secondary circuit if the primary refrigerant circuit exceeds a certain charge size
Gas sensors	Gas sensors are be mandated for certain situations to initiate mitigation measures such as ventilation, alarms, terminating electrical supplies, etc. These may be applicable to systems using flammable refrigerants in machinery rooms or even for systems in occupied spaces.

## Minimum Charge Size

According to EN 378: Part 1, the maximum allowable charge size (Equation 1) for a given room and the minimum required room size (Equation 2) for a given split AC unit with flammable refrigerant charge can be calculated

$$(1) \quad m_{\max} = 2.5 \times \text{LFL}^{5/4} \times h_0 \times A^{1/2}$$

$$(2) \quad A_{\min} = m^2 / (2.5 \times \text{LFL}^{5/4} \times h_0)^2$$

$m_{\max}$ : maximum allowable refrigerant charge [kg]

$m$ : refrigerant charge [kg]

$A_{\min}$ : minimum required room size [m<sup>2</sup>]

$A$ : room size [m<sup>2</sup>]

LFL: lower flammability limit [kg/(m<sup>3</sup>)]

$h_0$ : installation height [m]

Installation Height [m]	0.6	1	1.4	1.8	2.2	2.6	3
Refrigerant Charge [g]	Minimum room size (m <sup>2</sup> )						
200	63	23	12	7	5	3	3
250	99	36	18	11	7	5	4
300	142	51	26	16	11	8	6
350	193	70	36	21	14	10	8
400	253	91	46	28	19	13	10
450	320	115	59	36	24	17	13
500	395	142	73	44	29	21	16

## Sources of Ignition

Precautions should be taken to avoid the possibility of direct sources of ignition from exposed electrical contacts. **Electrical items that have the potential to produce electrical sparks during normal operation** should receive particular attention to eliminate them as potential sources of ignition. The following methods can be applied:

- Insulate terminals
- Locate within IP65 enclosure
- Replace with solid state type component
- Replace with Ex type component
- Locate externally

NOTE: Care should be taken to ensure that electrical terminations, including capacitor terminations are adequately tightened and secured against loosening and that adequate insulation is provided to avoid live parts shorting together.

Motors, including fans, pumps and compressors should be of brushless design. Components to consider as possible sources of ignition are: On/off manual switches Liquid level switch Condensate pump switch Thermostats Flow switches Fan speed controllers Pressure switches Start relays Humidity controllers Oil differential switches Thermal overload relays

Programmable controllers Fan delay switches Potential relays Defrost timers/switches Contactors Universal relays Time switches/relays Isolator switches

**NOTE: This list is not exhaustive.**



## **Hot Surfaces** (All)

Parts of refrigerating machines whose surfaces could become excessively hot shall be avoided. All components that could come into contact with released refrigerant shall have a maximum surface temperature not higher than 100K below the auto-ignition temperature of the refrigerant used.

## **Marking and Instructions**

- 1. Marking of Systems Installed on Site*
- 2. Marking of Compressors and Unit Systems*
- 3. Marking of Pipes*
- 4. 'Flammable Gas' Stickers*
- 5. Instructions*

## **General considerations for workshop/manufacturing**

Production areas within factories and workshops require additional precautions in addition to those detailed in other sections. Whilst the scope of this publication does not allow for detailed coverage of these requirements, the following lists items that should be considered.

### ☐ **Storage and handling of hydrocarbon refrigerant cylinders**

- (a) General requirements
- (b) Open air storage
- (c) Storage within specially designed buildings and outhouses
- (d) Storage within parts of a building

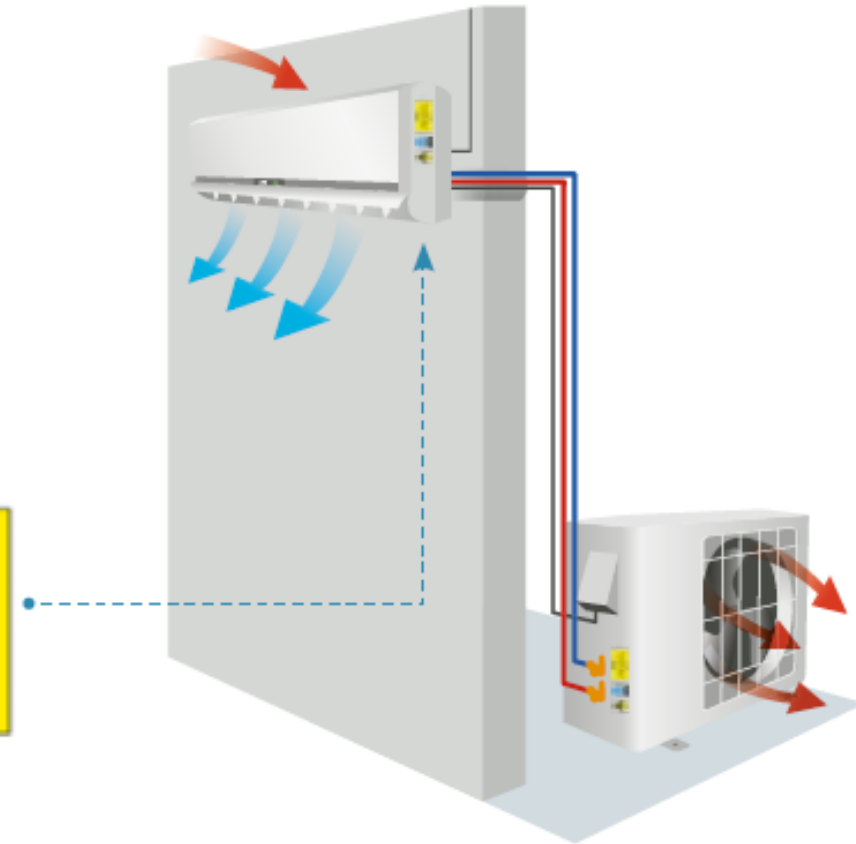
### ☐ **Bulk storage installations**

- (a) Location, separation and security requirements
- (b) Underground and mounded vessels

# SAFE DESIGN AND CONSTRUCTION

Ensure that anyone initiating work on the system is made aware of the presence of flammable refrigerant inside and as far as possible the precautions they should take.

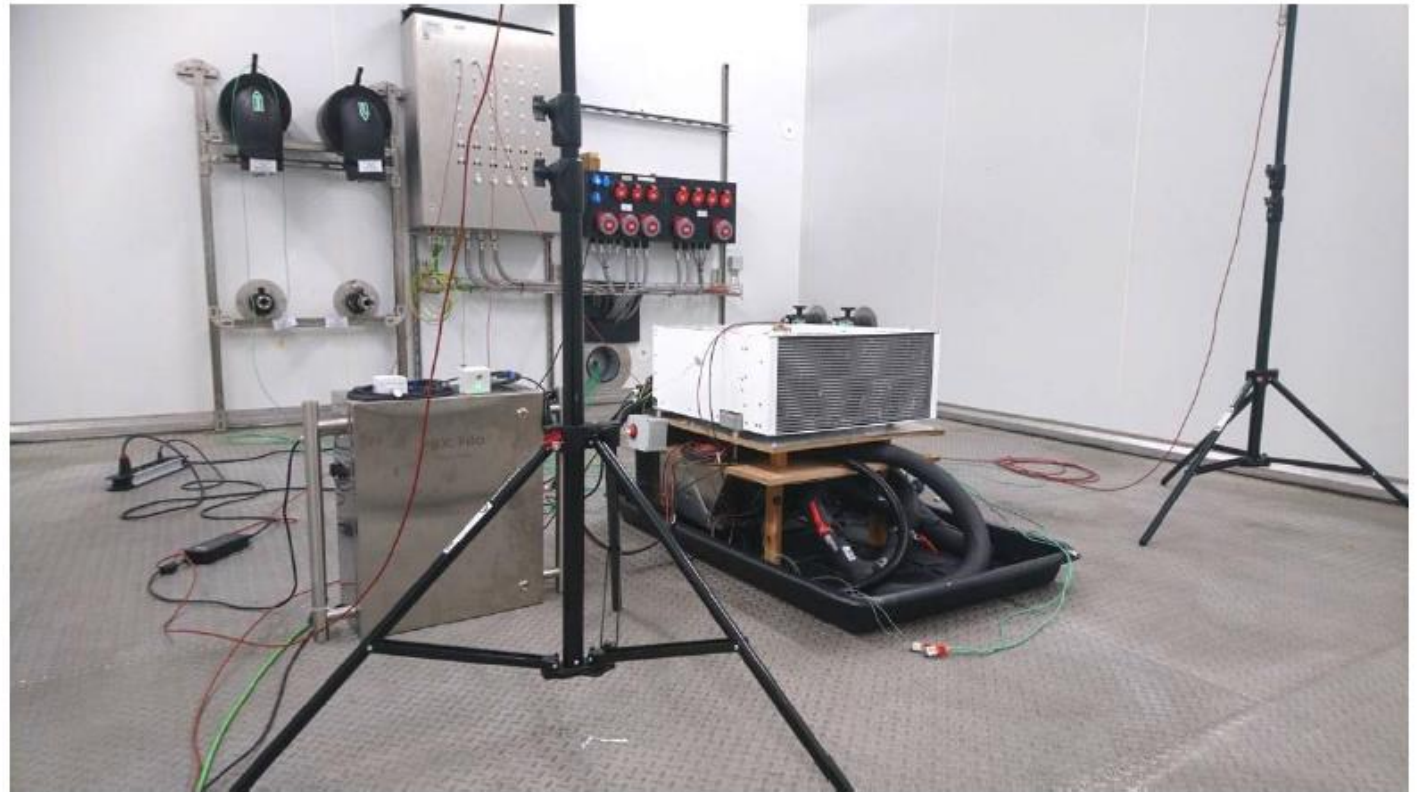
- Flammable refrigerant signage visible on indoor and outdoor unit
- Flame symbol and instruction manual symbol on parts subject to maintenance or repair
- Warning label for room requirement
- Installation/service/operation manual
- Signage and instruction for transportation on packaging for pre-charged equipment.



# Intensive Validation and Performance Tests



Shock and Vibration Tests



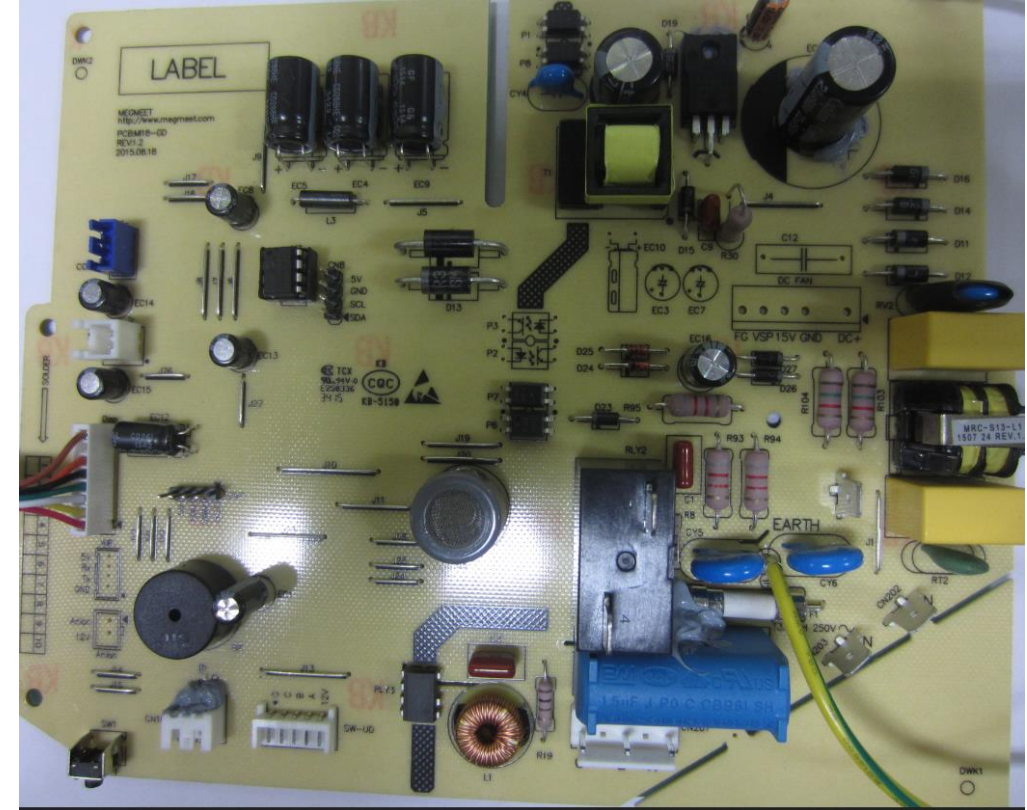
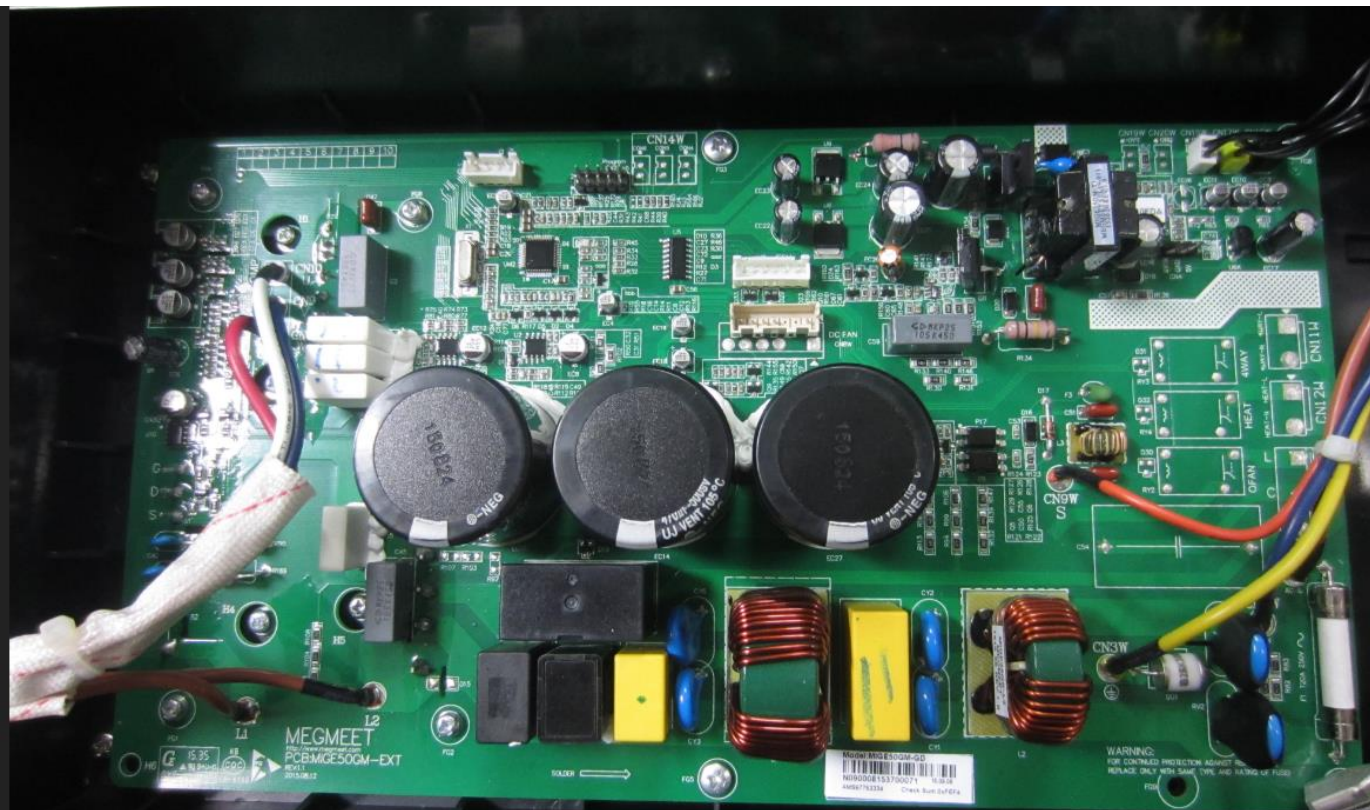
High Temperature and EMC Test



# SAFE DESIGN AND CONSTRUCTION

Design and development of Hardware and software

- ✓ Controller Development.
- ✓ Compressor Development.
- ✓ EEV Development.
- ✓ Software Algorithm
- ✓ Sensors and control.
- ✓ Enclosure and Safety.

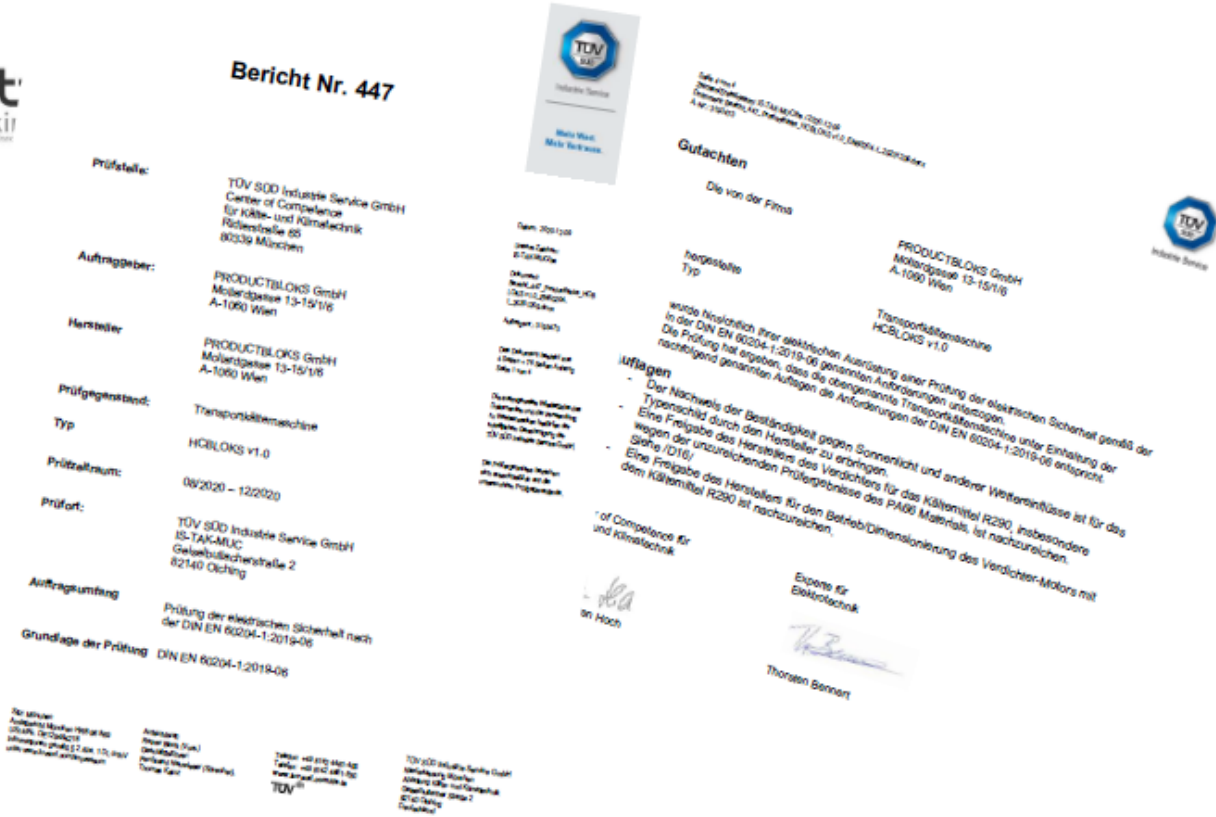




# Compatibility and Certification



Close to: Test results are not to be used for any other purpose without the written consent of the test institute.



## **General Approach to Hydrocarbon Refrigerant Handling**

All flammable refrigerant gases when mixed with air form a flammable mixture. The effect of ignition of such a mixture can be severe. It is therefore important that the appropriate safety requirements are observed at all times when working with flammable refrigerants. Any equipment used in the process of repair must be suitable for use with flammable refrigerants. All tools and equipment (including measuring equipment) are to be checked for suitability for working on the equipment, particular attention is to be paid to the selection of:

- ☐ Refrigerant recovery units.
- ☐ Refrigerant leak testing units
- ☐ Electrical test meters
- ☐ Refrigerant recovery cylinders
- ☐ Portable lighting

If the installation permits, it is recommended that the equipment be removed from its existing position to a controlled workshop environment suitable for the type of repair where work can be conducted safely.

### **Safety checks**

- *General work area*
- *Checking for presence of refrigerant*
- *Presence of fire extinguisher*
- *No ignition sources*
- *Ventilated area*
- **Checks to the refrigeration equipment**
- **Checks to electrical devices**
- **Detection of Hydrocarbon Refrigerants**

# R 290 Experience

## Manufacturing Setup

Gas charging station with ventilation ducting & gas alarms



Repair area gas recovery system with ducting & gas alarm interlock



Fire proof junction boxes in Refrigerant charging areas





# The impact and Application of flammable refrigerants to the servicing sector

## **SERVICE, MAINTENANCE AND REFRIGERANT HANDLING**

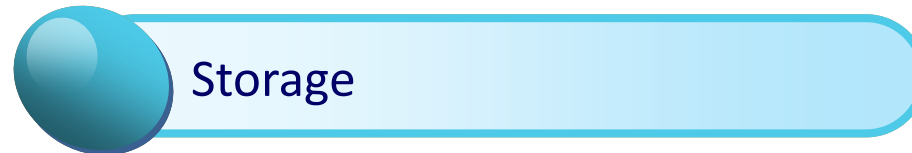
Any person who is involved with working on or breaking into a refrigerant circuit should hold a current valid certificate from an industry accredited assessment authority, which authorizes their competence to handle refrigerants (including hydrocarbons) safely in accordance with an industry recognized assessment specification. Servicing shall only be performed as recommended by the equipment manufacturer. Maintenance and repair requiring the assistance of other skilled personnel shall be carried out under the supervision of the person competent in the use of flammable refrigerants.





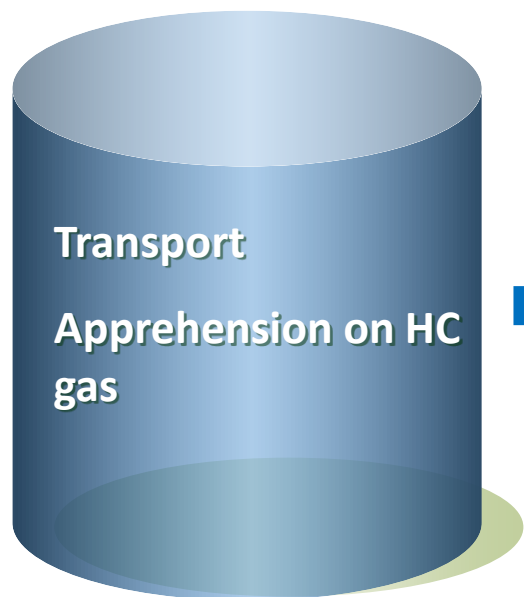


## Basics





# Basics – Handling & Transport



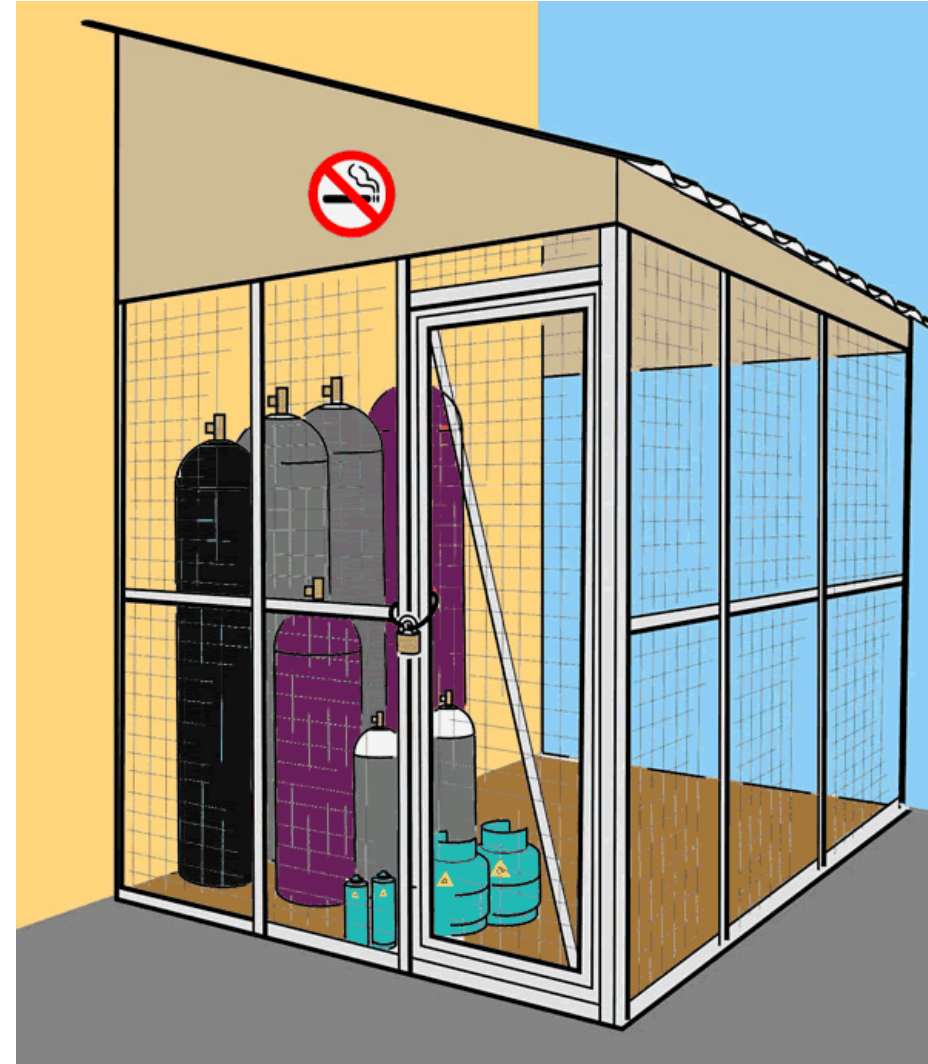
- Safe handling and storage of refrigerant cans
- Perform sealed system repairs preferably in workshop to avoid refrigerant handling
- Providing gas cans with 150 grams charge which is as per the safety norms





### Cylinder Storage --

- 😊 In a locked cage
- 😊 At ground level
- 😊 Away from air intakes to building
- 😊 Remote from ignition sources
- ☹ No smoking



# Servicing Hydrocarbon systems – Good Practices

Coupling of  
Joints using  
flared nut



Cutting of Copper Tubes  
with Tube cutter



Deburring using reamer



Surface cleaning



Good leak free flare



Flaring

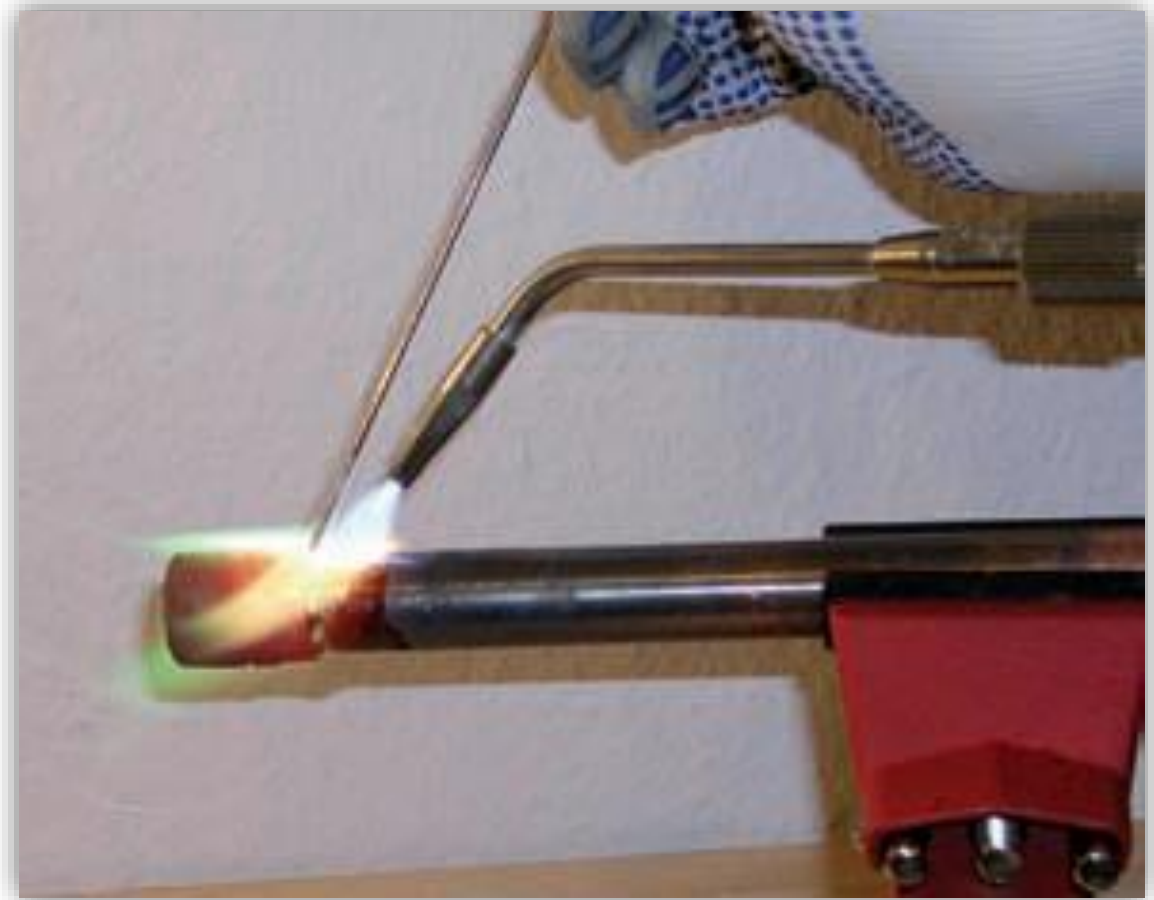


Locking of Flare Tool



# Servicing Hydrocarbon systems – Good Practices

- Brazing of Tubes should be done only by Certified Brazers to ensure leak proof Joints
- **AC example** - The total Length of Connecting Tubes between IDU and ODU should not exceed more than **6 meters**.



Brazing of Copper Tubes

# Servicing Hydrocarbon systems – Good Practices



Standard Operating procedures for Sealed system repairs:

- Charging by Weight
- Getting vacuum below 500 Microns
- Leak testing with OFDN

are mandatory procedures which have to be followed by the technicians

Sealed system  
services/repairs



SOP

GSP's Followed during Repairs

# Safe working Practice



Education, Support and Training on local, national and international levels, are the keys to success!

- Aside from the environmental benefits of Hydrocarbon Refrigerants I have found them to be far better for performance, efficiency and energy savings. I have never experienced serious component failure or malfunction when using Hydrocarbon Refrigerants.
- However, as a Refrigeration Engineer, working in the private sector, I cannot afford to educate the general population as to the benefits of Natural Refrigerants. This education needs to be achieved through help from Governments, Worldwide Environmental Groups and Technical Associations.





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**“The most effective (and maybe the only one) way to achieve the climate neutrality goals as soon as possible lies in the quick reduction of F-Gas by scaling up natural refrigerant-based solutions across the sectors”**





**GESS**

**Thank you for  
listening!**

**Anwar Shaikh**

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<https://globalgess.com/>

