



HFO-1234yf
- Development & Implementation -

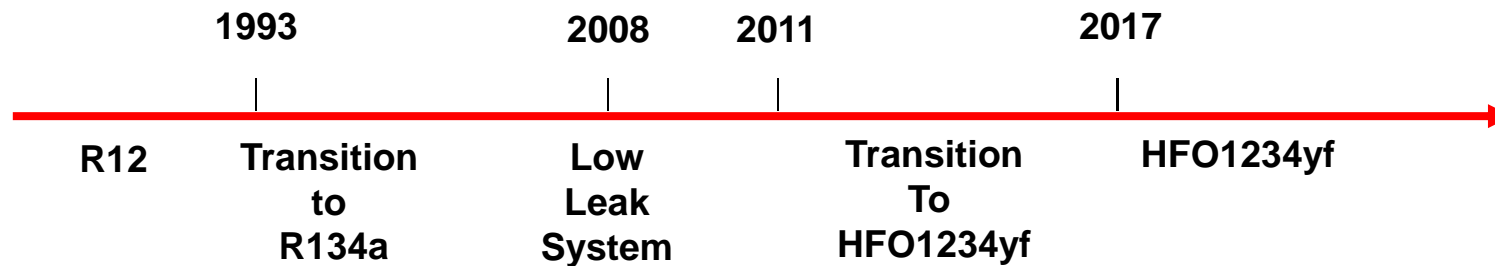
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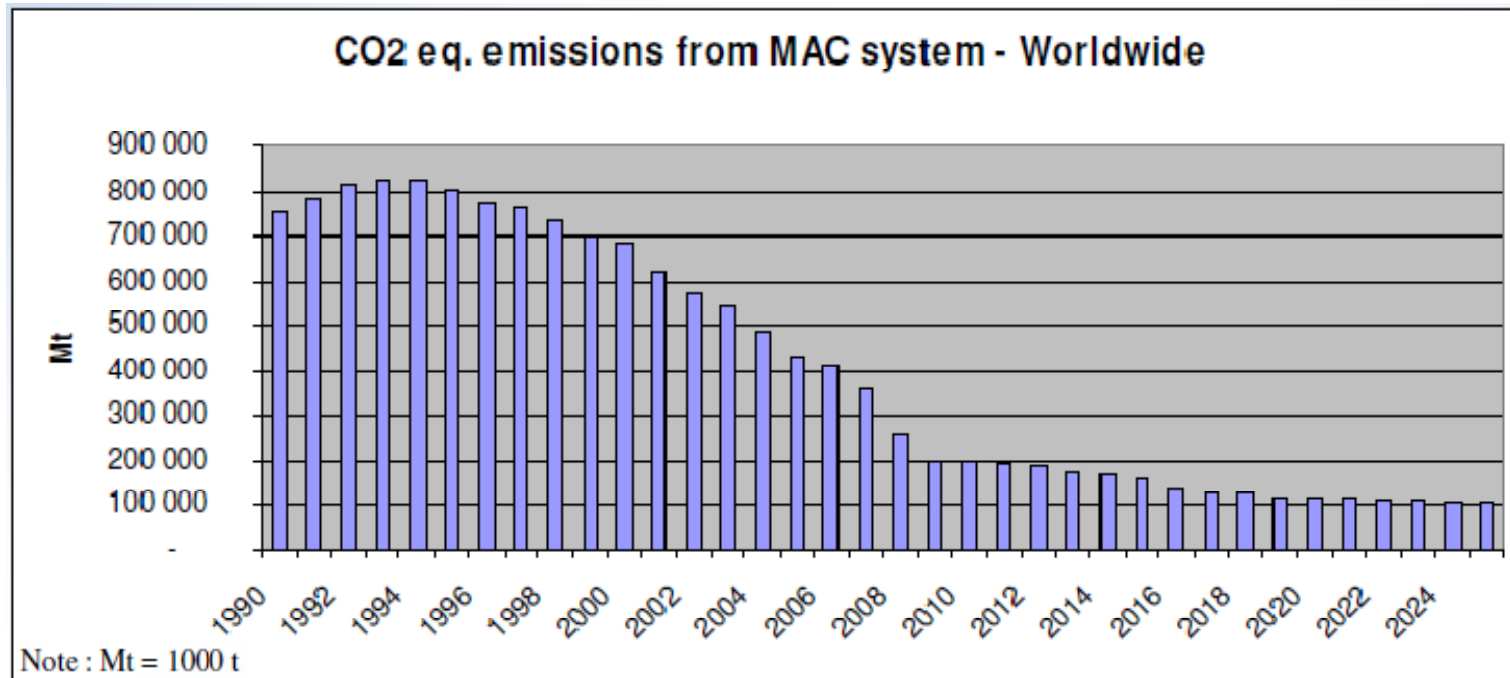
Introduction

- ❑ EU Mac Directive 40/2006, refrigerant with GWP >150 will be phased out progressively between 2011 and 2017



- ❑ US GHG Regulation EPA-420-F-09-047a implemented 1-Apr-10 OEM tailpipe CO₂ and CAFE mpg credits available for adopting advanced technologies including LGWP refrigerants

Introduction



Clodic et al., Milan 2009

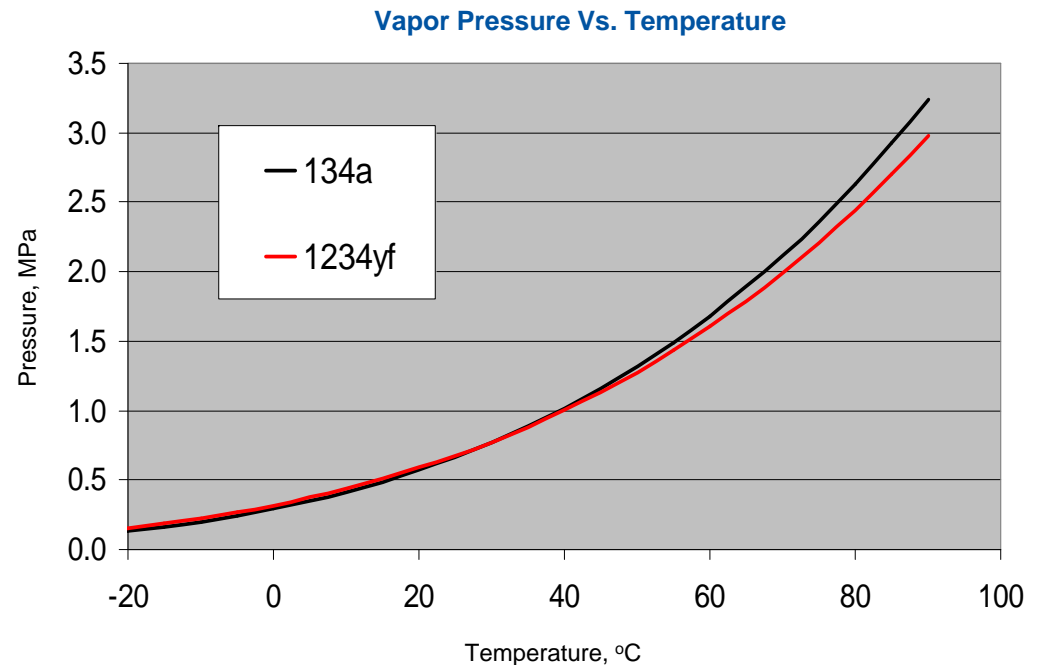
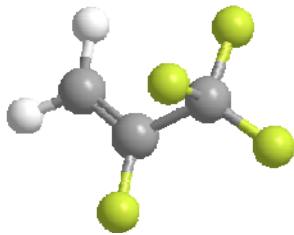
Transition to Low GWP refrigerant will have an important impact on GHG emissions

HFO-1234yf Development

1234yf – $\text{CF}_3\text{CF}=\text{CH}_2$

- Honeywell initiated R&D on low global warming programs about a decade ago .
- After an extensive program of work, Honeywell identified HFO-1234yf as a close match to HFC-134a.

	HFO-1234yf	R134a
ODP	0	0
GWP	4	1430
Atm. life	11 days	12 years
Tb (°C)	-29	-26
Tc (°C)	95	101



Toxicity & Registrations

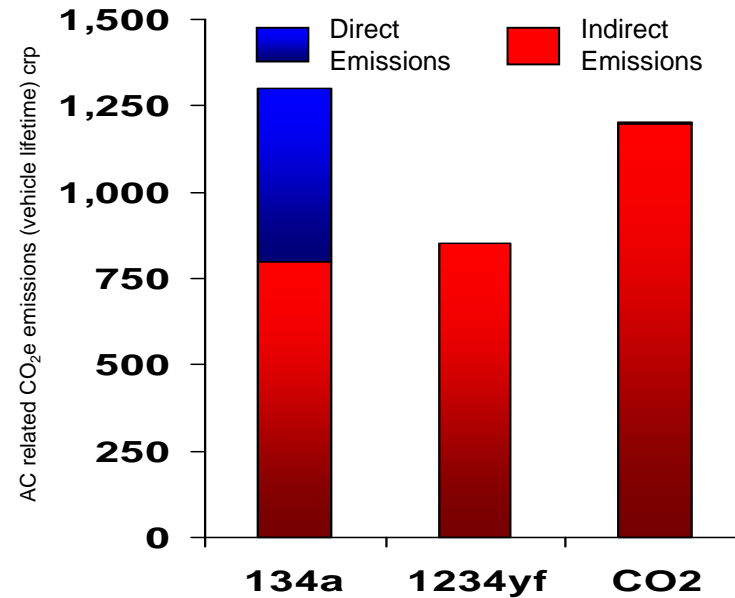
	HFO-1234yf	R134a
Acute Lethality	✓	✓
Cardiac Sensitization	✓	✓
4 week toxicity	✓	✓
13 week toxicity	✓	✓
Genetic Toxicity	✓	✓
Developmental Toxicity	✓	✓
Reproductive Toxicity	✓	✓

Regulatory Approvals

- Registered under REACH for 1,000+ mt/yr
Registered for air conditioning & refrigeration use.
- U.S. PMN & SNAP applications in progress.
- Japan notification approved.
- S. Korean notification approved.
- Canada, China & Australia in preparation

HFO-1234yf is ASHRAE Class A refrigerant with Low Toxicity & REACH Registered

Environmental Performance

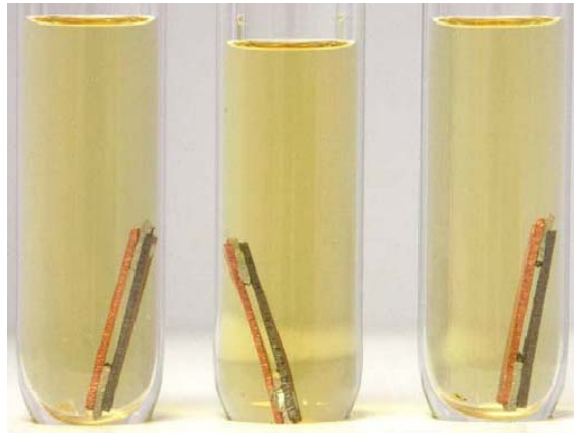


- Lowest carbon footprint of all AC Technologies
- Significantly higher energy efficiency than CO₂

HFO-1234yf: Environmentally the Best Choice

Refrigerant Stability

Thermal Stability



Vehicle Validation

COMPONENT	1234yf Apr-08 Lot BX043	Vehicle 1 158,000 km 10 months	Vehicle 2 160,000 km 10 months	Vehicle 3 160,000 km 10 months
R-1234yf, %	99.97	99.5	99.4917	99.5415
R-134a* (system contaminant), %	ND	0.4433	0.4335	0.4209
Sum R-1234yf + R-134a*	99.97	99.9433	99.9252	99.9624
R-1225yeZ, ppm	98	173	130	105
Other Refrig. Impurities, ppm	194	296	398	222
Unknowns by FID, ppm				
high MW containments (oil)	0	124	220	56

R-134a* = Original R134a charge and impurities

Storage Stability

- 2 year test with refrigerant stored in warehouse
- Refrigerant before and after are identical
- NO refrigerant degradation

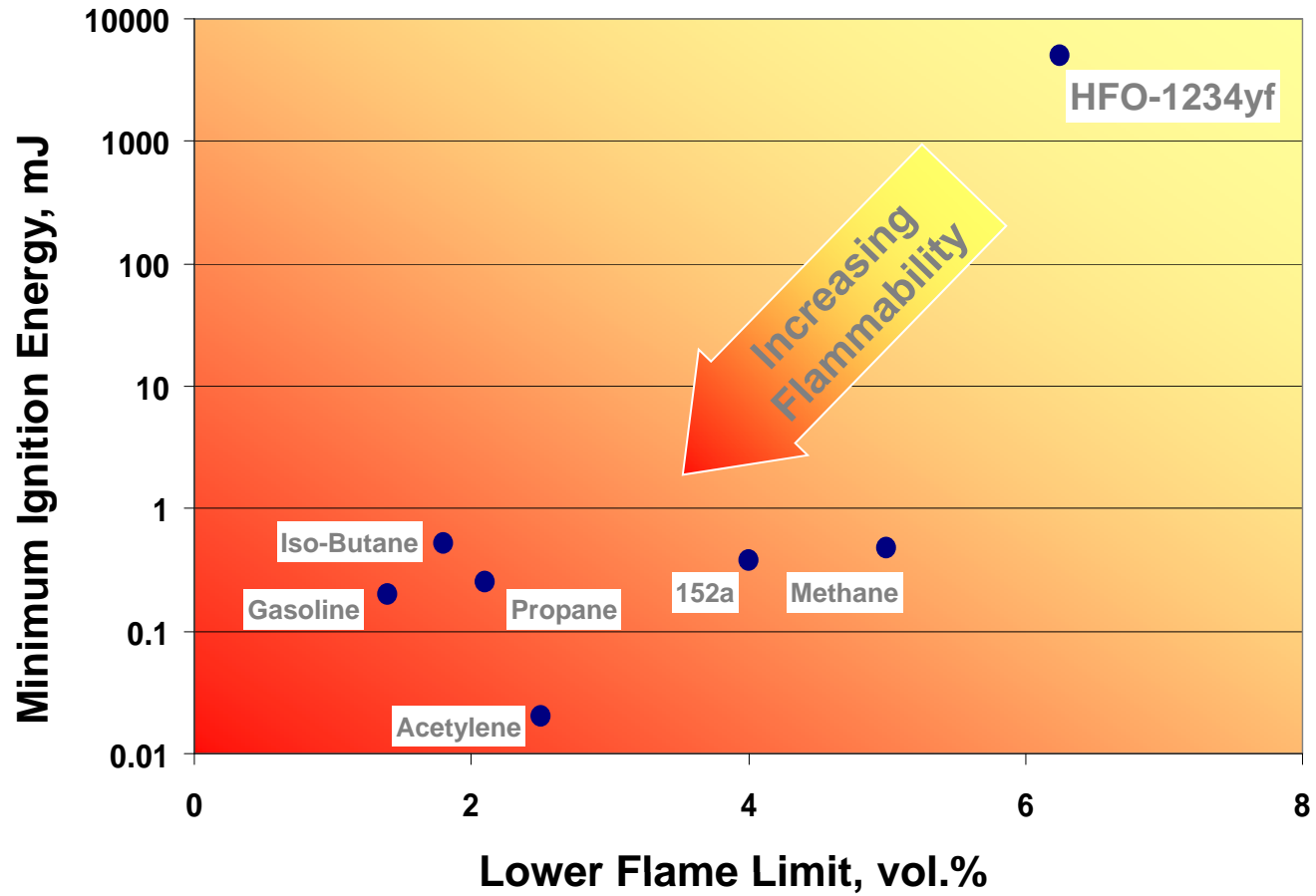
Flammability Characteristics

- Flammable Range of 6.2 Vol. % (LFL) to 12.3 Vol. % (UFL) in air.
- Minimum Ignition Energy, 5,000 -10,000mJ
 Tests conducted in 12 liter flask to minimize wall quenching effects.
- Autoignition Temperature, 405°C
- Heat of Combustion, 11.8MJ/kg (composition 7.73% in air)
- Fundamental burning velocity, 1.5 cm/s (per ISO 817, Measured by AIST, Japan)



HFO-1234yf can be described as having low flammability

Flammability Comparison



CRP 1234

- **Research was conducted over the last two years at international laboratories to access the best available expertise.**

Issues Investigated include:

- Safety and risk assessment
 - Toxicity
 - Flammability
 - Air-conditioning system efficiency and performance
 - Material compatibility
- **Phase 1 completed in Feb, 2008**
 - **Phase 2 completed in Apr, 2009**
 - **Phase 3 completed in Nov, 2009**
 - More extensive data are now available confirming suitability of HFO-1234yf as the next auto a/c working fluid
 - Fault trees have been greatly expanded
 - Consideration of additional scenarios

HFO-1234yf SAE Standards

SAE System Design Standards

- J639 Provides requirements and identifies SAE J Standard requirements for MAC systems
- J2772 Measurement of Passenger Compartment Refrigerant Concentrations under system refrigerant leakage conditions.
- J2773 R-744 and HFO-1234yf Refrigerant Standard for Safety and Risk Analysis for use in Mobile Air Conditioning Systems
- J2772 Measurement of Passenger Compartment Refrigerant Concentrations under system refrigerant leakage conditions
- J2842 HFO-1234yf and R-744 Design Criteria and Certification for OEM Mobile Air Conditioning Evaporator and Service Replacements
- SAE J2064 R-134a and HFO-1234yf Refrigerant Automotive Air-Conditioning Hose and Assemblies

SAE Refrigerant Standard

- J2844 Refrigerant Purity and Container Requirements for New HFO-1234yf Refrigerant Used in Mobile Air-Conditioning Systems

SAE Service Equipment Standards

- J2843 HFO-1234yf Recovery/Recycling/Recharging Equipment for Flammable Refrigerants for Mobile Air-Conditioning Systems
- J2851 HFO-1234yf Refrigerant Recovery Equipment for Mobile Automotive Air-Conditioning Systems
- J2888 HFO-1234yf Service Hose, Fittings and Couplers for Mobile Refrigerant Systems Service Equipment
- J2912 HFO-1234yf Refrigerant Identification Equipment for Use with Mobile Air Conditioning Systems
- J2913 HFO-1234yf Refrigerant Electronic Leak Detectors, Minimum Performance Criteria

SAE Technician Requirements

- J2845 Technician Training for Safe Service and Containment of Refrigerants Used in Mobile A/C Systems (R-744 and HFO-1234yf)

SAE Certification Standard

- SAE J2911 Procedure For Certification That Requirements For Mobile Air Conditioning System Components, Service Equipment and Service Technicians Meet SAE J Standards

- SAE J1739 [Issued July 1994 Revised June 2009] Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA), and Potential Failure Mode and Effects Analysis for Machinery (Machinery FMEA)

HFO-1234yf SAE Standards Summary

New Standards Developed in conjunction with refrigerant evaluation, addressing system design, equipment and Technicians

5 new standards added

Documents	R-134a	HFO-1234yf
J639	✓	✓
Refrigerant Purity	✓	✓
Measurement Compartment Concentrations		✓
Risk Analysis		✓
Evaporator Design		✓
Refrigerant Recovery	✓	✓
Recycle Charging Equipment		
Leak Detectors	✓	✓
Refrigerant Identification	✓	✓
Technician and Equipment Certification		✓
Technician Training		✓
Hose Assemblies	✓	✓ New Field Coupled

HFO-1234yf Implementation

What Is ATEX ?

ATEX is the name commonly given to the framework for controlling explosive atmospheres and the standards of equipment and protective systems used in them. It is based on the requirements of two European Directives

- The first directive (**1994/9/EC, or “ATEX95”**) sets minimum health and safety standards to **equipment** to ensure that workers can work safely in potentially explosive atmospheres.
- The second directive (**1999/92/EC, “ATEX137”**) sets minimum requirements for improving the safety and health protection of **workers** potentially at risk from explosive atmospheres. Employers are required to take appropriate technical and/or organizational measures with a view to preventing and providing protection against explosions.
 - The prevention of the **formation** of explosive atmospheres, or where the nature of the activity does not allow that,
 - The avoidance of the **ignition** of explosive atmospheres, and
 - The **mitigation** of the detrimental effects of an explosion so as to ensure the health and safety of workers.

Classification of Hazardous areas

Hazardous places are classified in terms of zones on the basis of the frequency and duration of the occurrence of an explosive atmosphere.

Likelihood of an explosive atmosphere			
High	Medium	Low	Improbable
flammable substance present continuously or for long period of time	flammable substance likely to occur in normal operation occasionally	flammable substance not likely to occur in normal operation but if it does occur persists for a short operation	Non hazardous place
ZONE 0	ZONE 1	ZONE 2	NO ZONE

Equipment Requirement

Special precautions need to be taken in hazardous areas to prevent equipments from being a source of ignition.

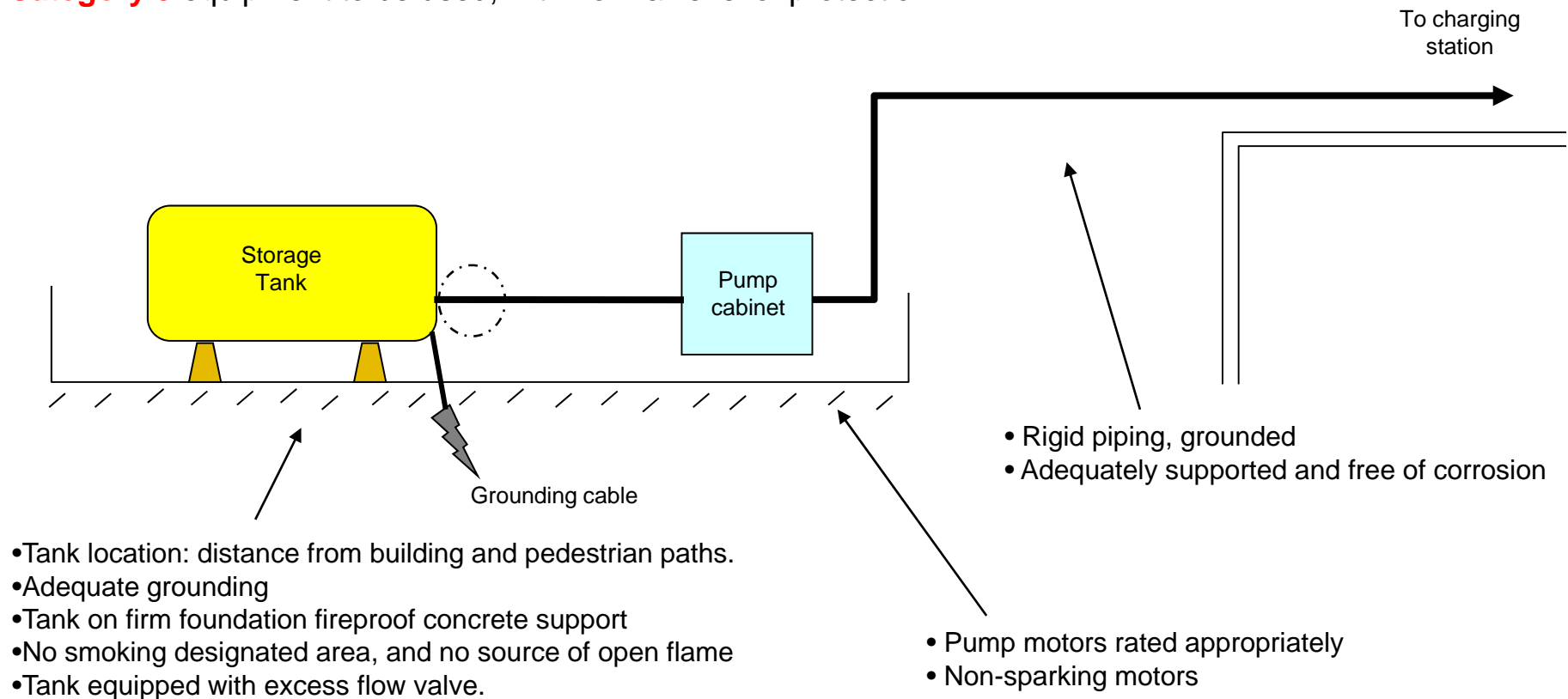
Equipment is categorised (1,2 or 3) to reflect the requirements of the various zones where it is intended to be used.

Equipment Category	Level of protection	Criteria	
Category 1	Very High	Required level of protection ensured by two independent means	ZONE 0
Category 2	High	Required level of protection ensured even in the event of frequently occurring disturbances or equipment faults which normally have to be taken into account	ZONE 1
Category 3	Normal	Ensures the required level of protection during normal usage	ZONE 2

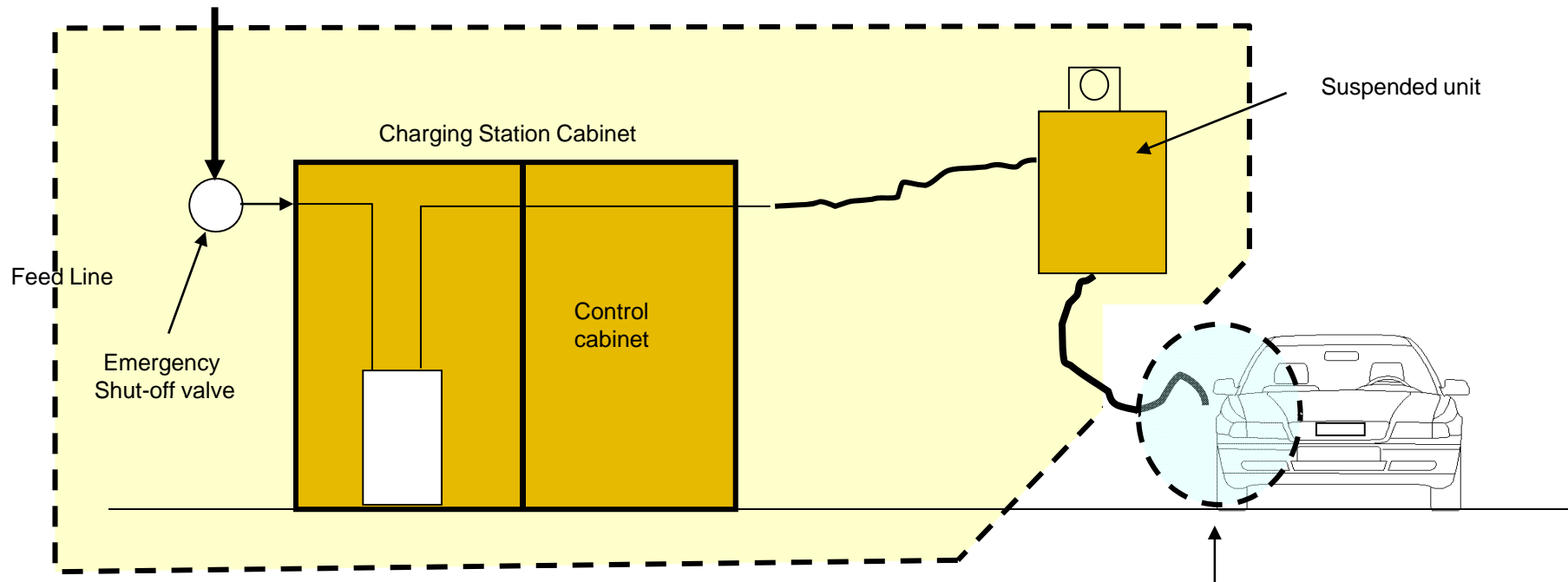
Outdoor ATEX

Flammable substance **not likely** to occur in normal operation but if it does occur persists for a short period: Likely to be a **ZONE2**

Category 3 equipment to be used, with normal level of protection.



Charging Station ATEX



flammable substance **not likely** to occur in normal operation but if it does occur persists for a short operation: **Zone2**

Action:

- Eliminate Zone through ventilation
 - If not possible avoid ignition sources
- In Zone 2 equipment self certification possible

flammable substance **likely** to occur in normal operation occasionally: **ZONE1**

Action:

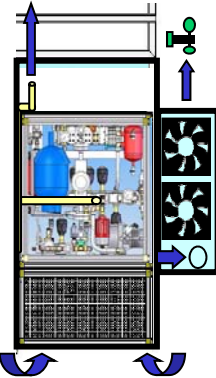
- Is ATEX small enough to be ignored (CFD)
- Eliminate Zone through ventilation
- If not possible avoid ignition sources

CINETIC FILLING : Concepts for HFO



Ventilated Concept

The target is to avoid any Div2/Zone2 area by ensuring a ventilation level in the cabinet to consider the diluted atmosphere as non hazardous.



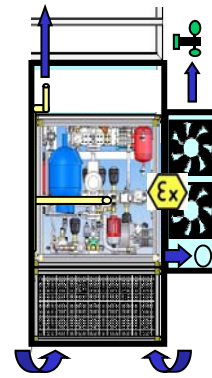
3 Solutions

- Fixed Forced Ventilation
- Onboard Forced Ventilation
- Global area Ventilation



ATEX Ventilated Concept

The target is to use adequate ATEX components for Div2/Zone2 area



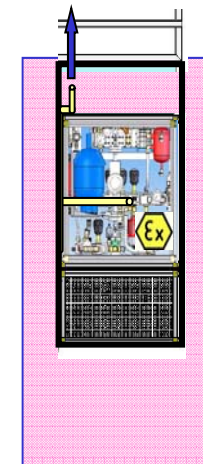
RapidCharge[®]

Product by CINETIC FILLING
A division of Fives group
www.fivesgroup.com



ATEX Concept

The target is to use adequate ATEX components for Div2/Zone2 area



AGRAMKOW: NO ZONE Concept

AGRAMKOW

The right fit



Non hazard area



NO Z ■ **NE** designed equipment

Conclusions

- **After a multiple year effort, automotive OEMs have concluded that HFO-1234yf can be the global replacement for R-134a.**
- **The implementation of HFO-1234yf would lead to an important reduction in MAC emission.**
- **Initial evaluations of both storage and charging systems indicated that HFO-1234yf can be implemented with modest changes to existing systems.**
- **The Honeywell implementation team can assist the automotive industry to transition to this environmentally superior air conditioning system refrigerant.**

Thank you!

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