2.6

Research on Flammability and Safety of Lower GWP Refrigerantds

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Tianjin University

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Contents

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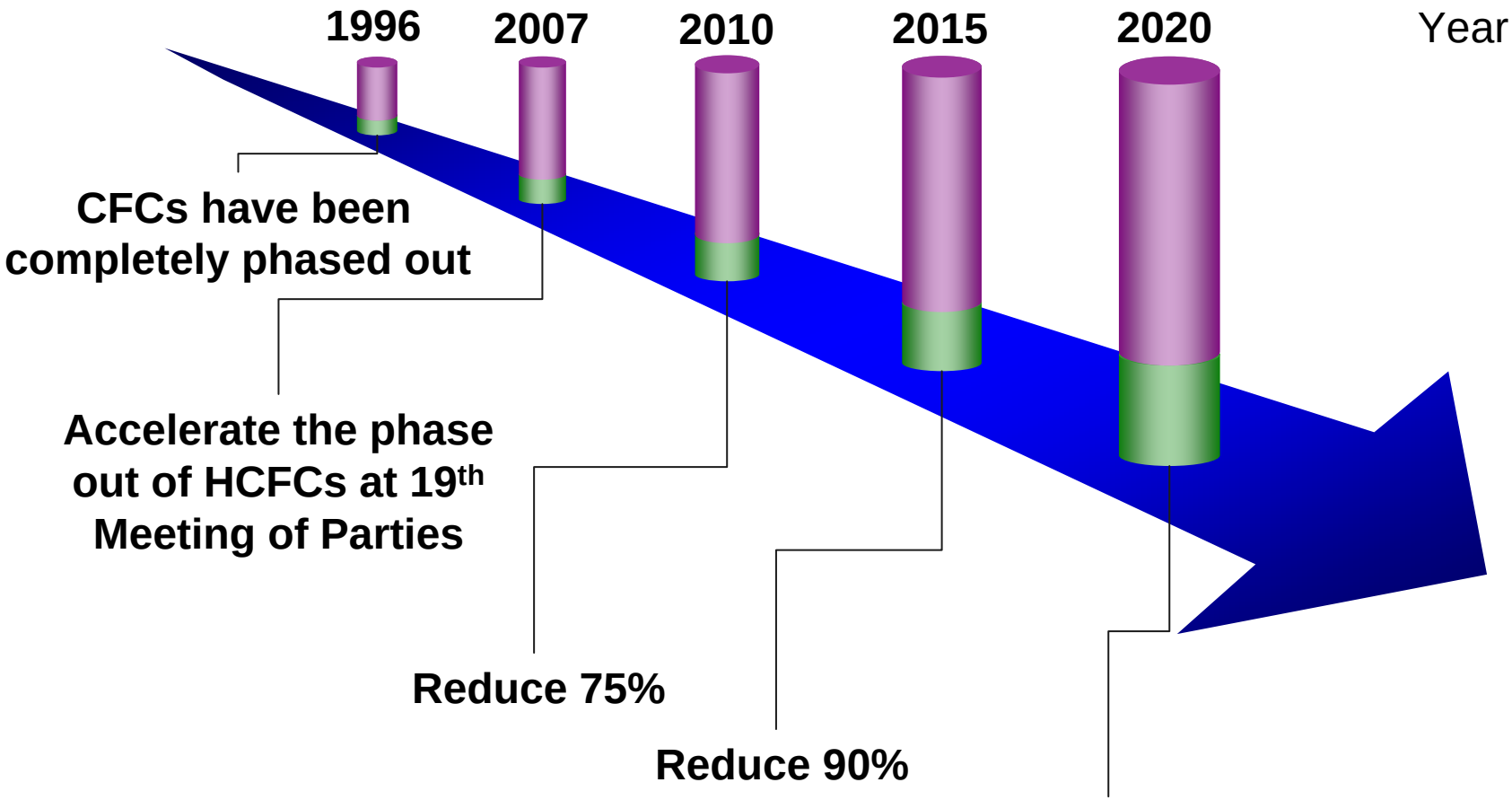
① Montreal Protocol-2007

For Developed countries



Elimination schedule about HCFCs in Montreal Protocol Amendment in 2007 for developed countries in 2007

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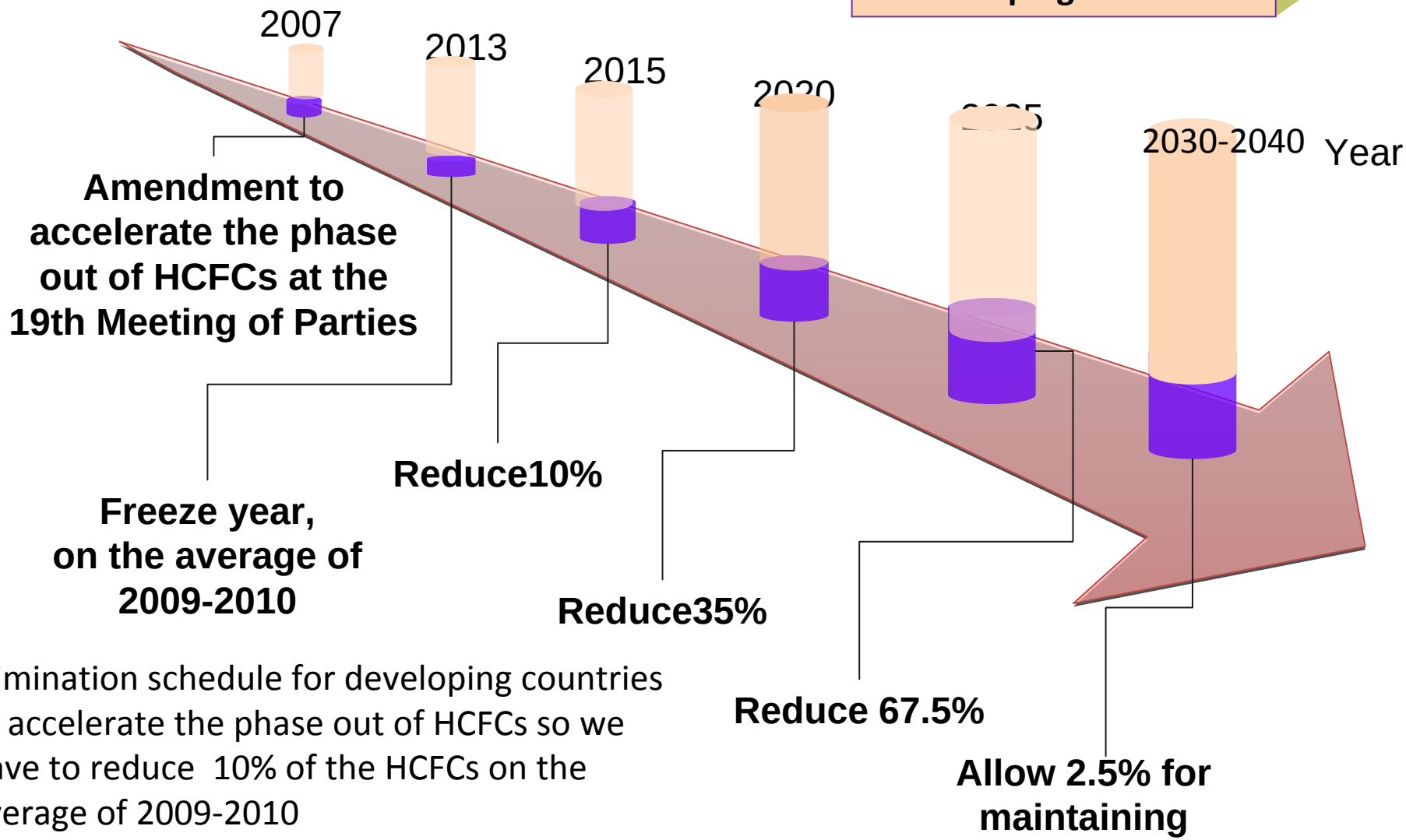
① Montreal Protocol-2007

For

Developing countries



Elimination schedule for developing countries to accelerate the phase out of HCFCs so we have to reduce 10% of the HCFCs on the average of 2009-2010

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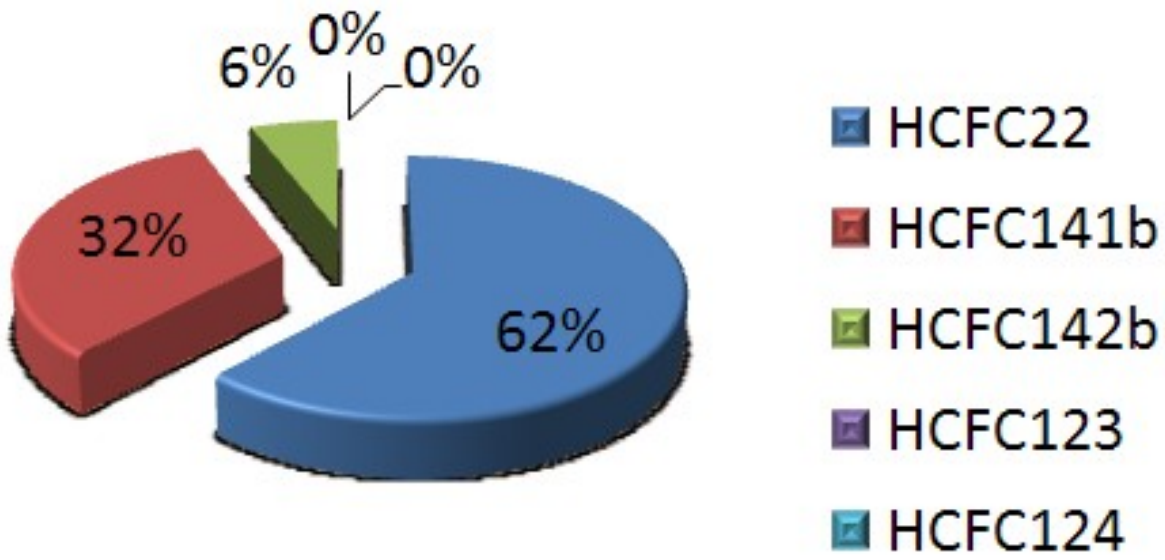
② Consumption Distribution of HCFCs in China

Consumption

Consumption of HCFCs in 2009 (180 Kt)



The most of them is R22

Source: XF,Zhou. Introduction of HCFCs phase-out situation,2010.

Global warming has been becoming more inportant problem

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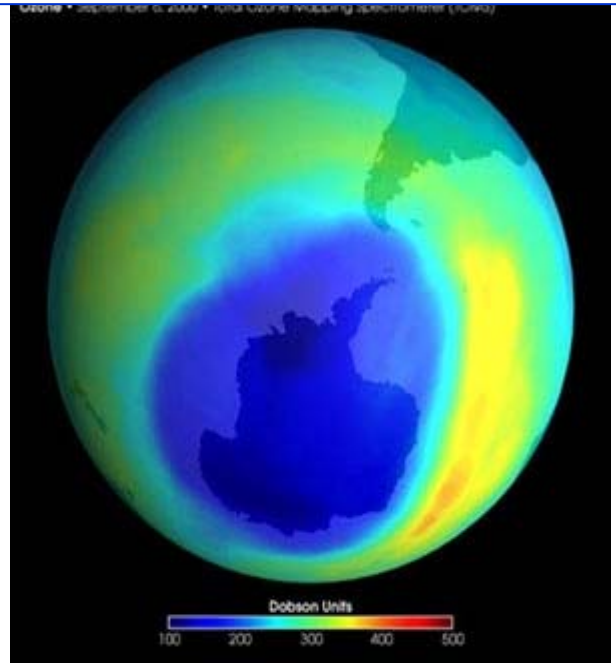


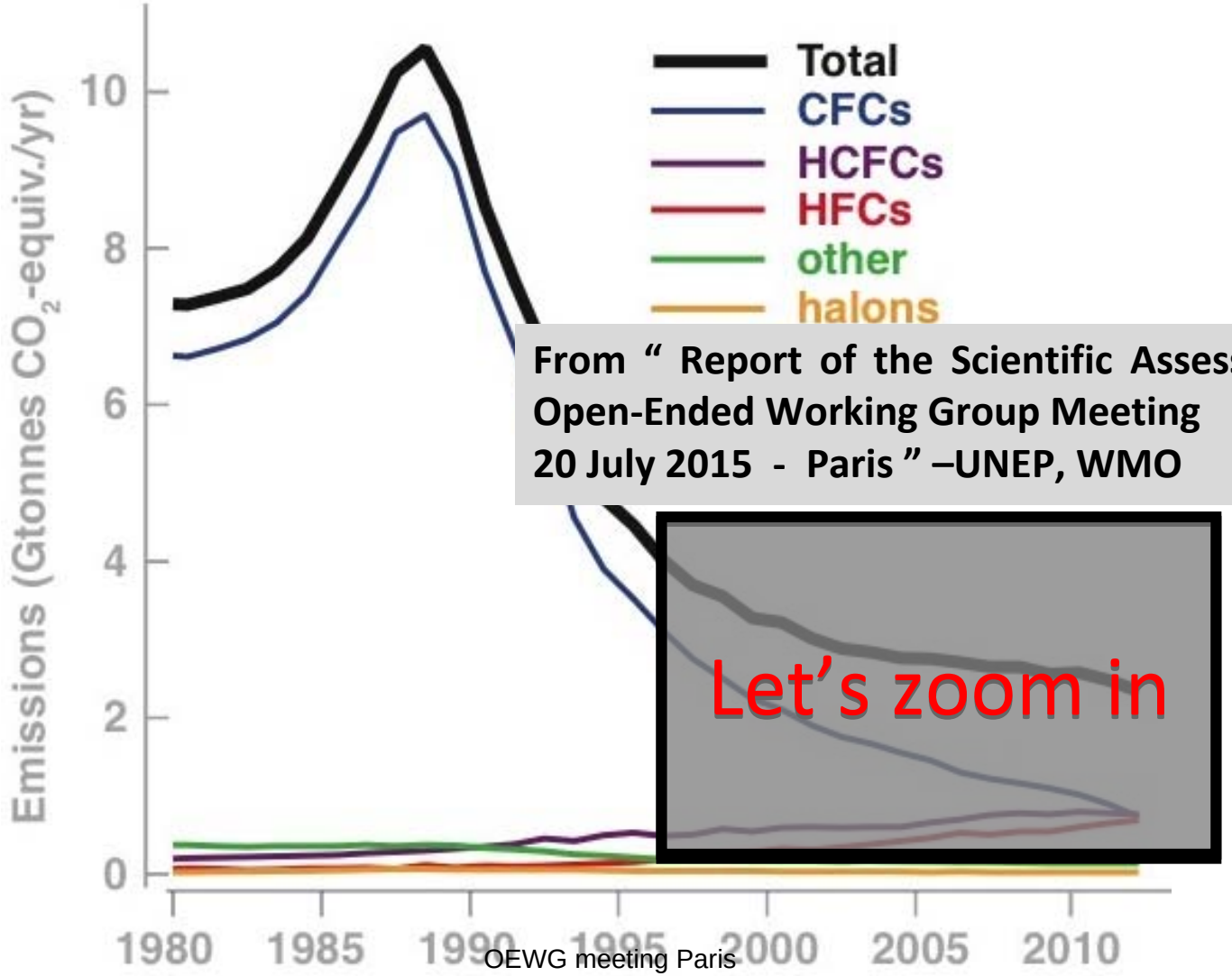
ODP **GWP**

Montreal Protocol **Copenhagen World Climate Conference**

0 ODP: has been basic requirement of newly-developed refrigerants

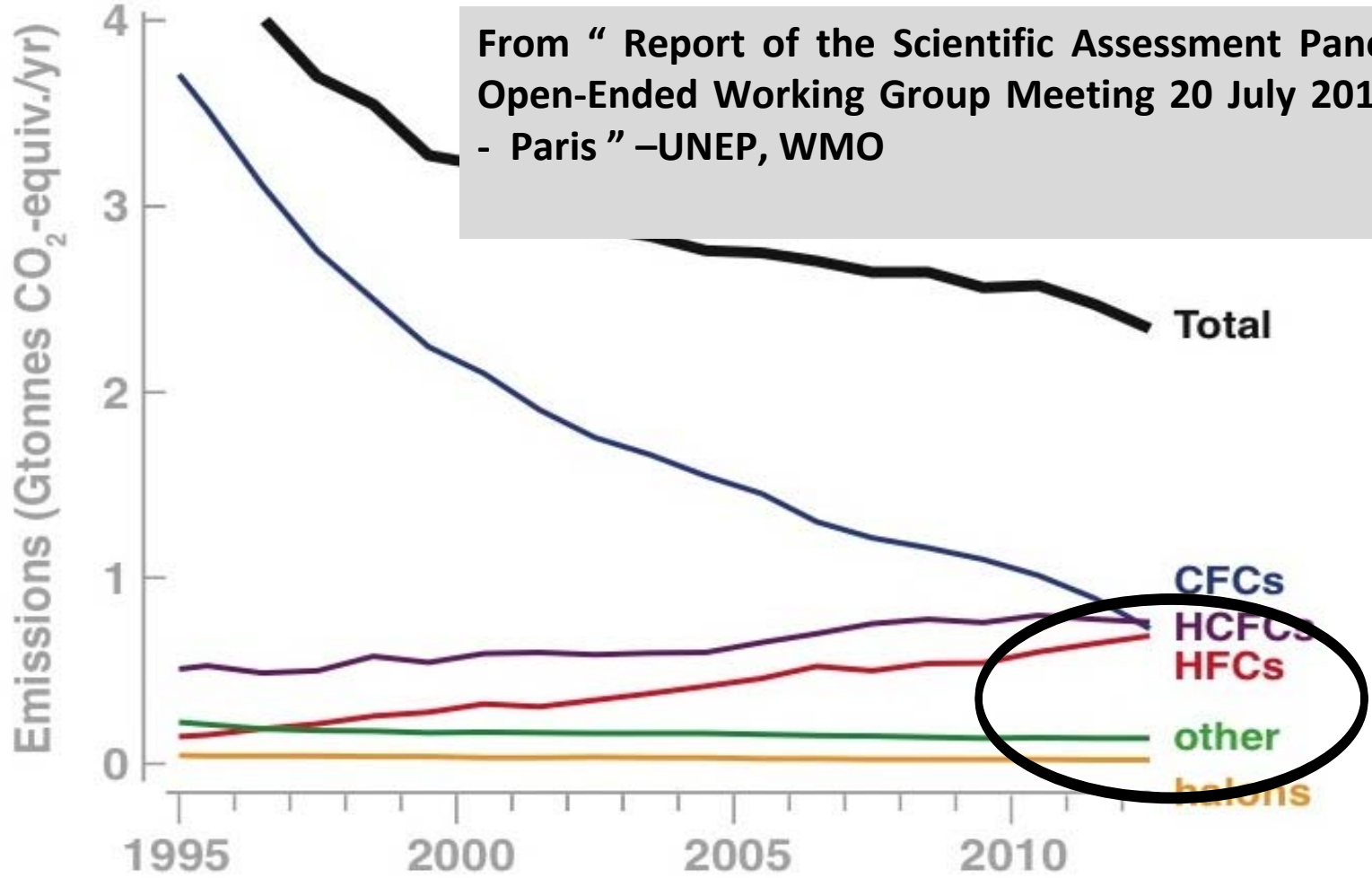
Global warming has been becoming more important problem all over the world

CFCs emissions continue to decline, but other compounds are increasing



From " Report of the Scientific Assessment Panel Open-Ended Working Group Meeting 20 July 2015 - Paris " –UNEP, WMO

In 2013, the emissions of CFCs, HCFCs, and HFCs were about equal in G tonnes CO_2-equivalent

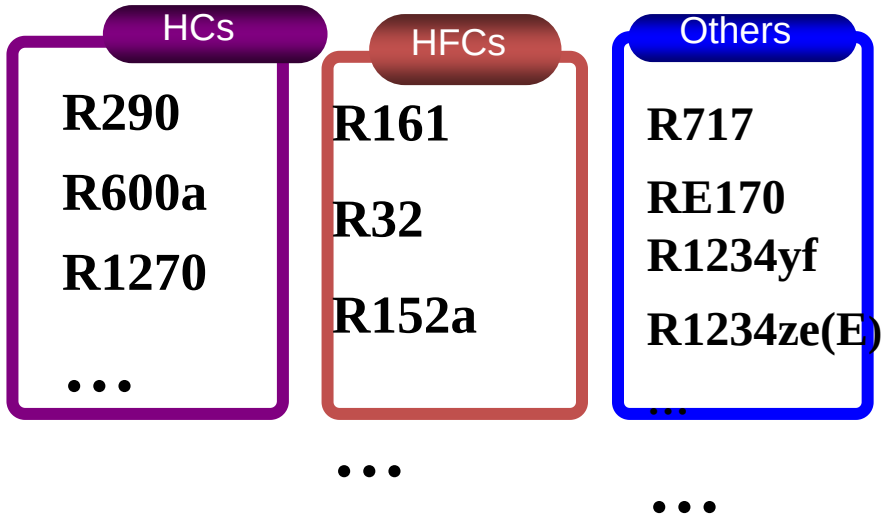


HCFCs and HFCs with higher GWP are increasing these years

1000 million

HCFCs alternatives with zero ODP and lower GWP

Zero ODP, lower GWP:



So developing new generation environmentally acceptable ref. with 0 ODP and Lower GWP becomes more and more important and emergency

But at present ,nearly all of the HCFC alternatives with zero ODP and lower GWP are flammable.

Such as:

- Lower GWP
- Alternatives

R1150 R290 R600a R600

R170 R1270 R601a R601

R161 R152a R32 RE170

R41 R1234yf R1234ze R717

Although they are all flammable, the flammabillties for them are different ,some of them are higher such as . And some of them are lower.

Application

Flammable refrigerants

GB 7144

There must be some risks in the process of life cycle of these equipments: production,operation,maintenance,recovery

图片引自百度图片

They will be widely used in air conditioners , heat pumps and cold storages

Fire Accident Example

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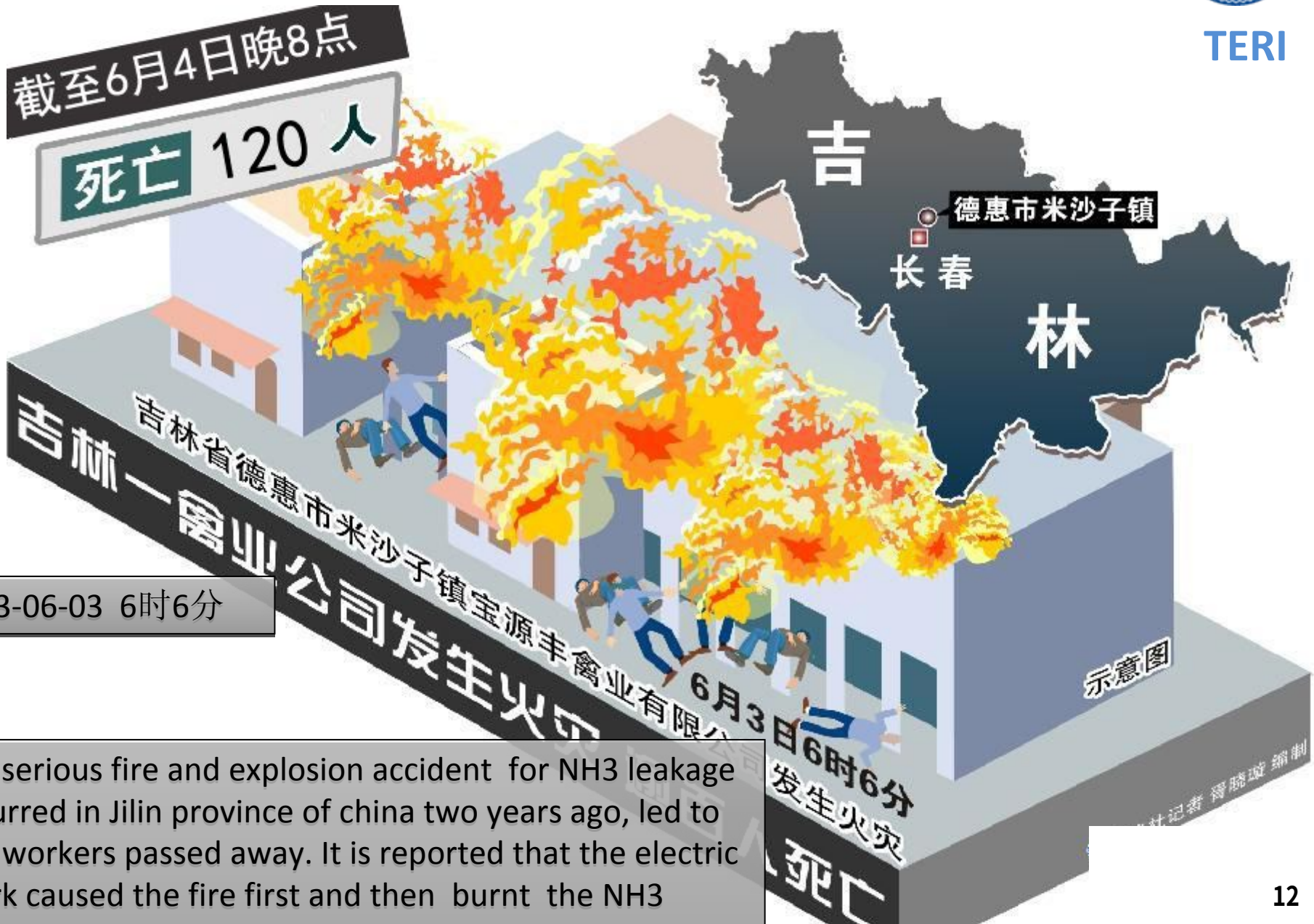

2013-06-03 6时6分

The serious fire and explosion accident for NH3 leakage occurred in Jilin province of china two years ago, led to 120 workers passed away. It is reported that the electric spark caused the fire first and then burnt the NH3

Flammability is an inescapable problem on the process of HCFCs elimination .

Special security arrangement and related standards should be proposed or updated ASAP !

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GB 4706.32-2012

Household and similar electrical appliances- Safety Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers

2013-05-01

- ① ***This standard and IEC 60335-2-40: 2005 are equivalent,***
- ② ***The flammable refrigerants*** (accordant with ASHRAE 34-2001, A2 and A3) ***are allowed to be used in heat pumps, air conditioners, and dehumidifiers.***
- ③ ***But there are special requirements or suggestions*** for systems using flammable refrigerants ***in the process of transport, storage, label, maintenance, detection, and recovery.***
- ④ ***Especially: there is a charge limit requirement for the refrigerating system***
-

This is the new chinese national standard issued 3 years ago. that is

So, safety particular requirement research for flammable refrigerants is very important and over the past several years we have been engaging in this work.

Contents

Our progress are including

① ***Review of the Chinese standards related to the flammable refrigerants*** **compared with the ISO and IEC standards**

② ***Collection and analysis on the safety measures of using flammable refrigerants (especially for A2L)***

③ ***Investigation on manufacture and application for the usage of flammable refrigerants***

④ ***Research on the flammability of lower GWP alternative refrigerants***

3) may be , there were twenty-one related companies to participate this investigation,

④

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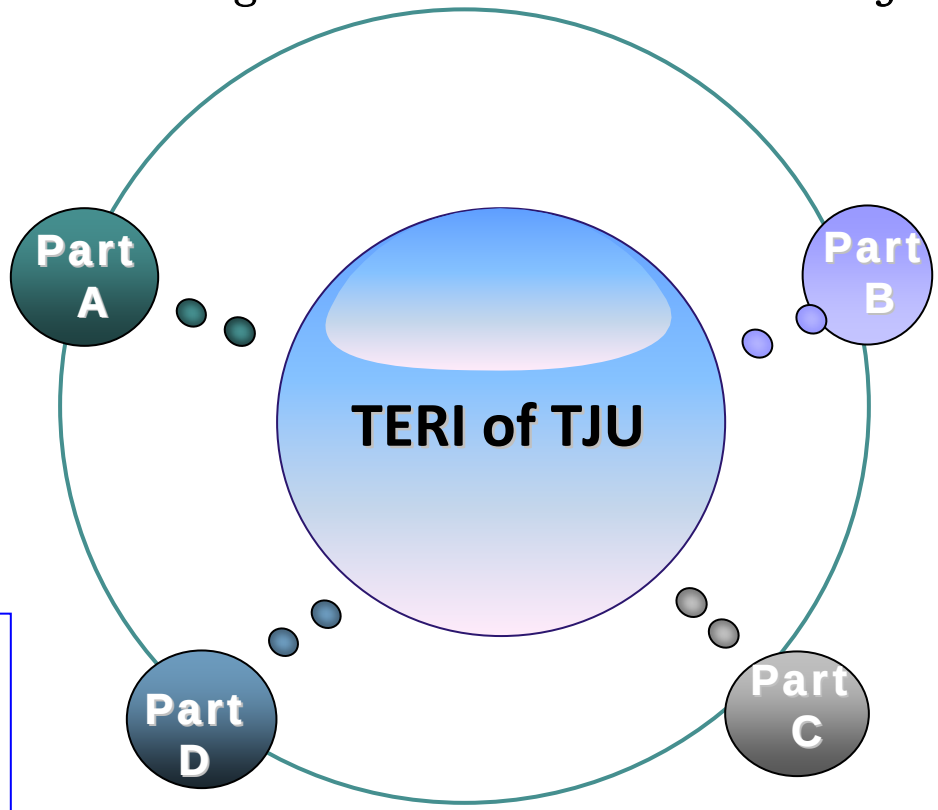
Our research topics on the flammability and safety of lower GWP alternative refrigerants in TERI of Tianjin University

A: Research on the flammable characteristics of new alternatives

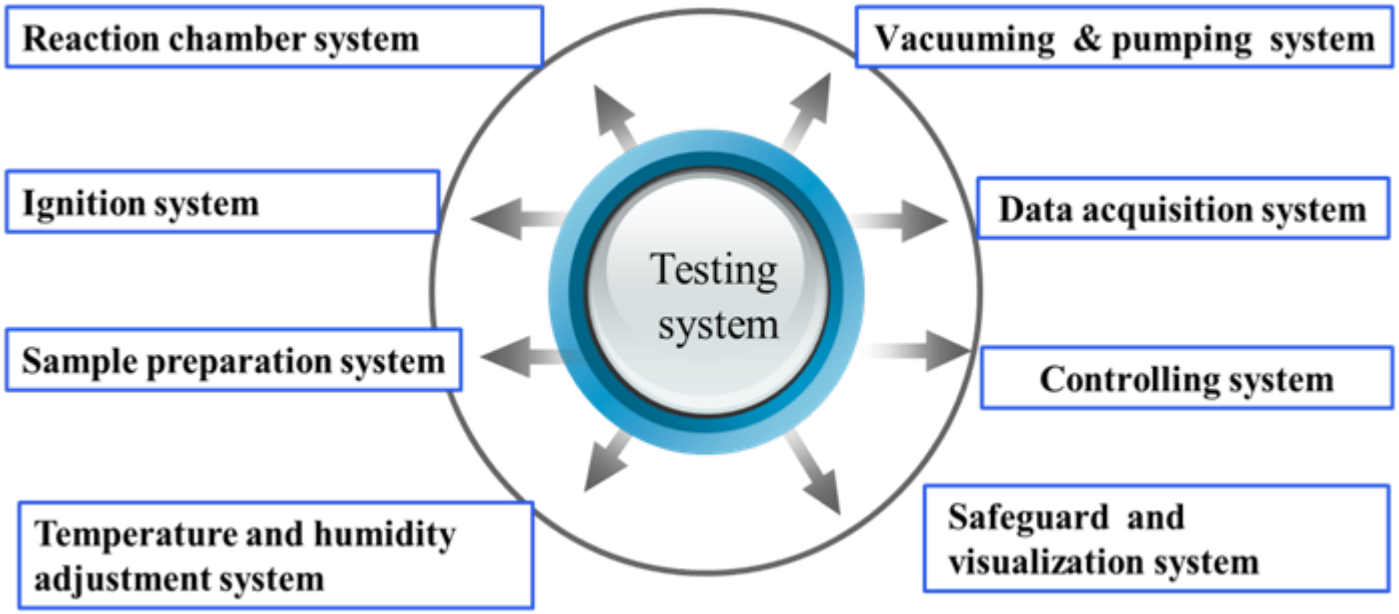


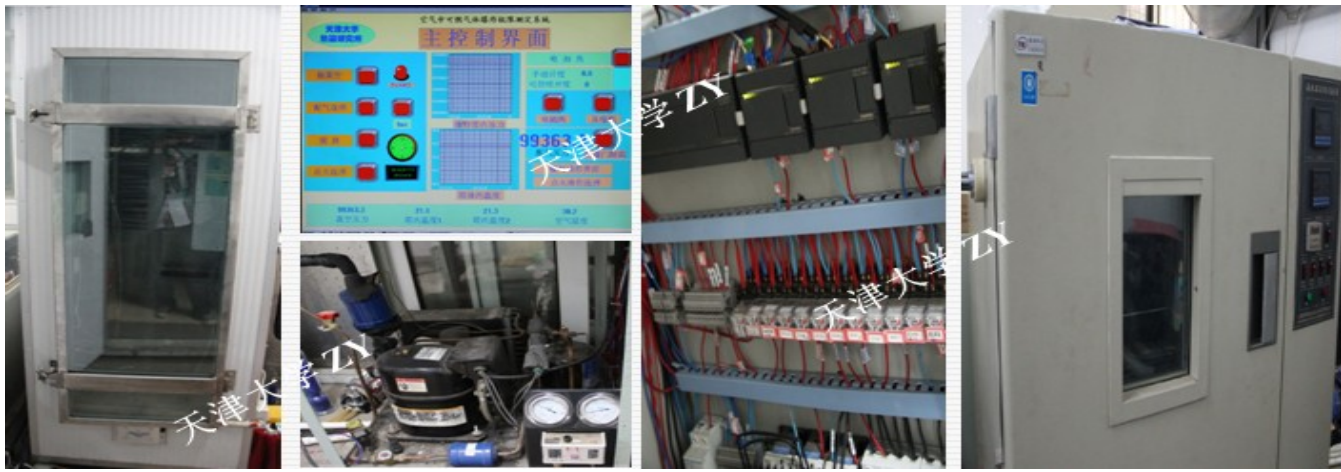
B: Flammability inhibitory technology for combustible refrigerants

D: fault tree analysis for risk assessment to flammable refrigerant system.

C: Research on the potential fire hazard by leakage

There are several research topics on the flammable alternatives that we are engaged in, including A,B,C,D.



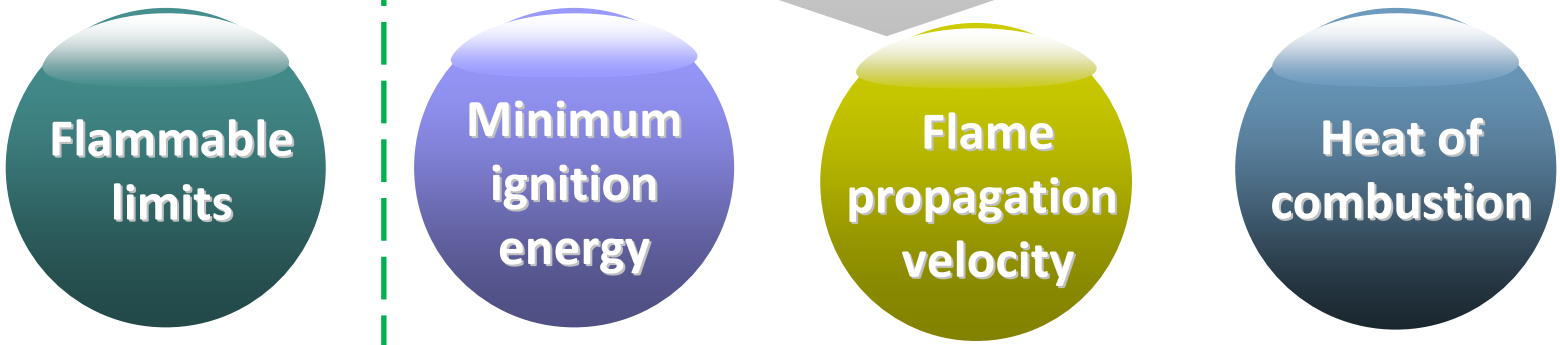


This is the structure of testing system of IERI for the characteristics of flammable alternatives

Four fundamental and vital parameters

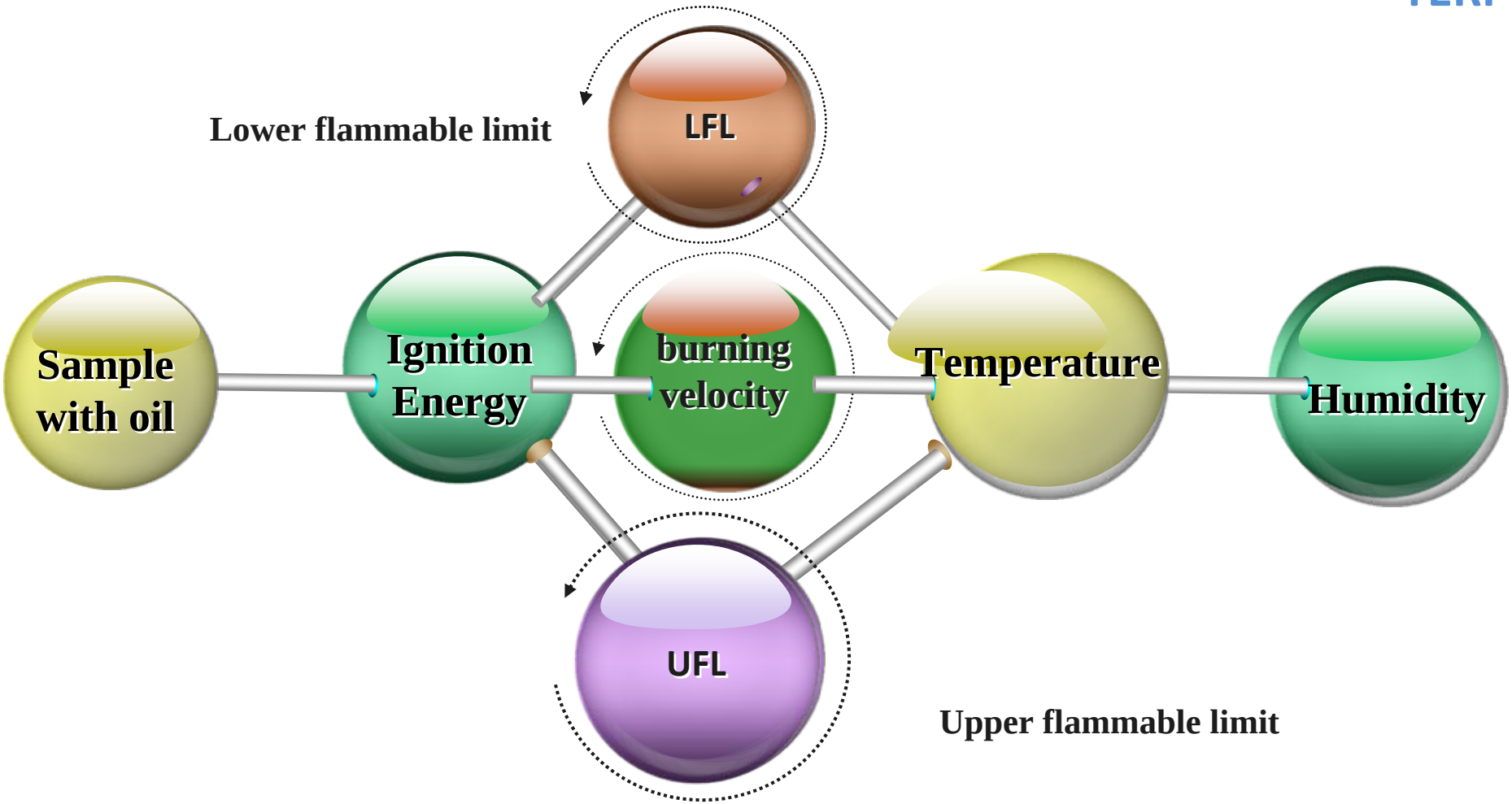
Among them flammable limits including lower flammable limit and uper flammable limits are very important properties to reflect the flammability of refrigerants

Ignited concentration;
Maximum allowable charge;
Refrigerants classification;



There are four fundamental flammable characteristics for flammable refrigerants, including:
LFL: ***means the minimum concentration of flammable gas in air below that the flame does not propagate to the top of reaction tube on contact with a source of electronic igniter.***
UFL: ***is defined as the maximum concentration of flammable gas in air above that the propagation of flame does not occur on contact with a source of electronic igniter.***

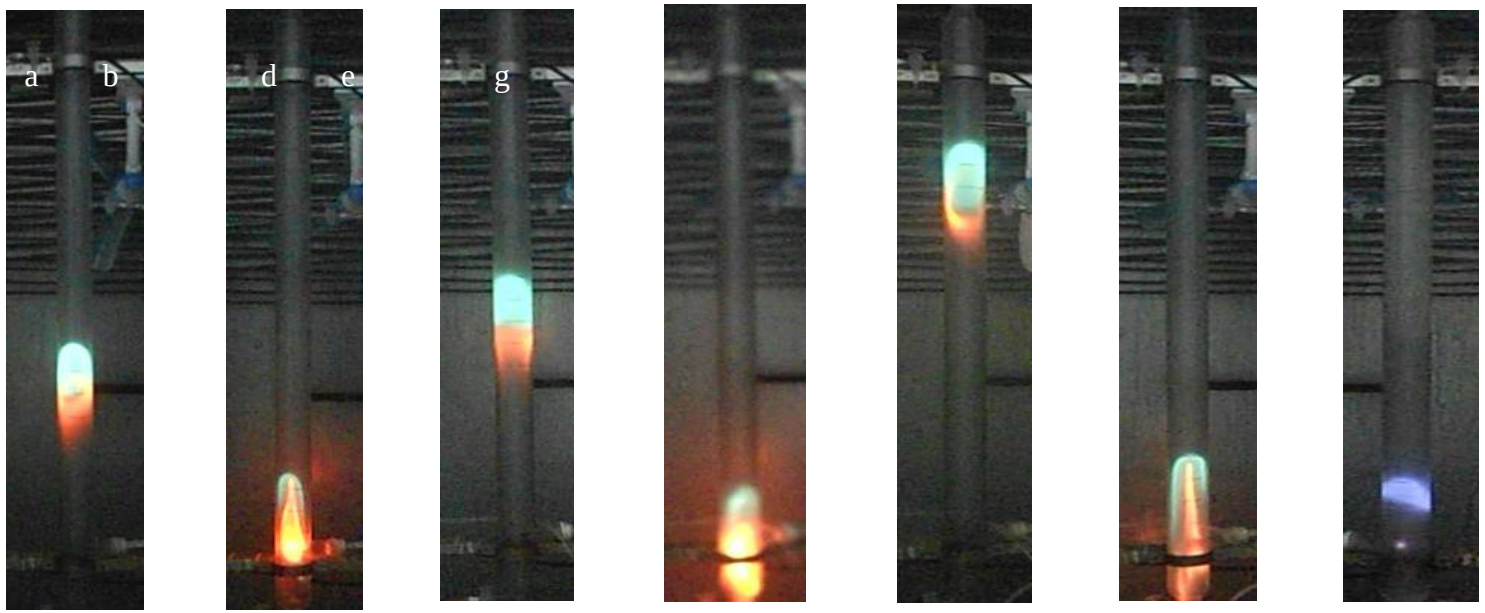
Research on the flammable limits of some new alternatives



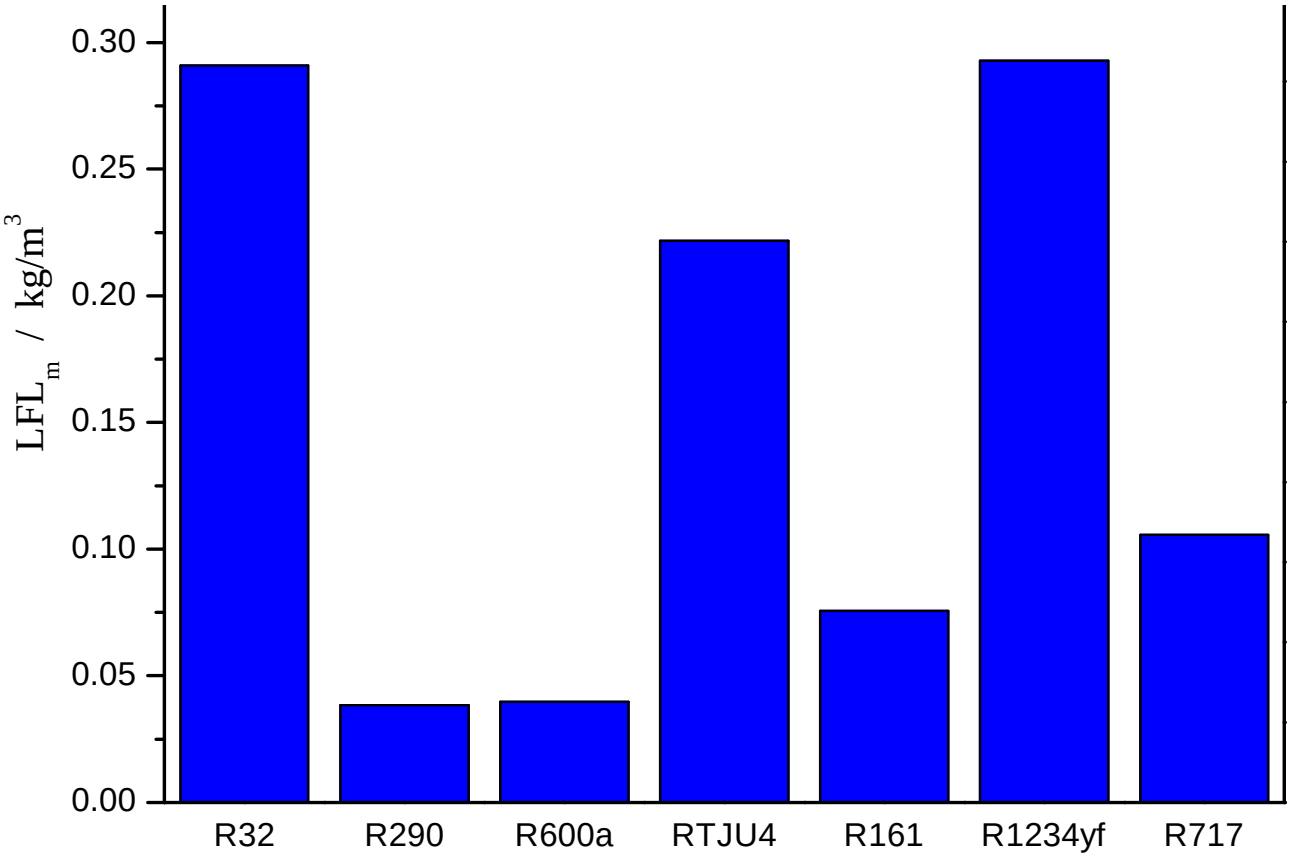
The testing research has been focused on the impacts on the flammable limits and burning velocities by surrounding air temperature, humidity, ignition energy and lubricant etc.

Some test results of TERI

TERI

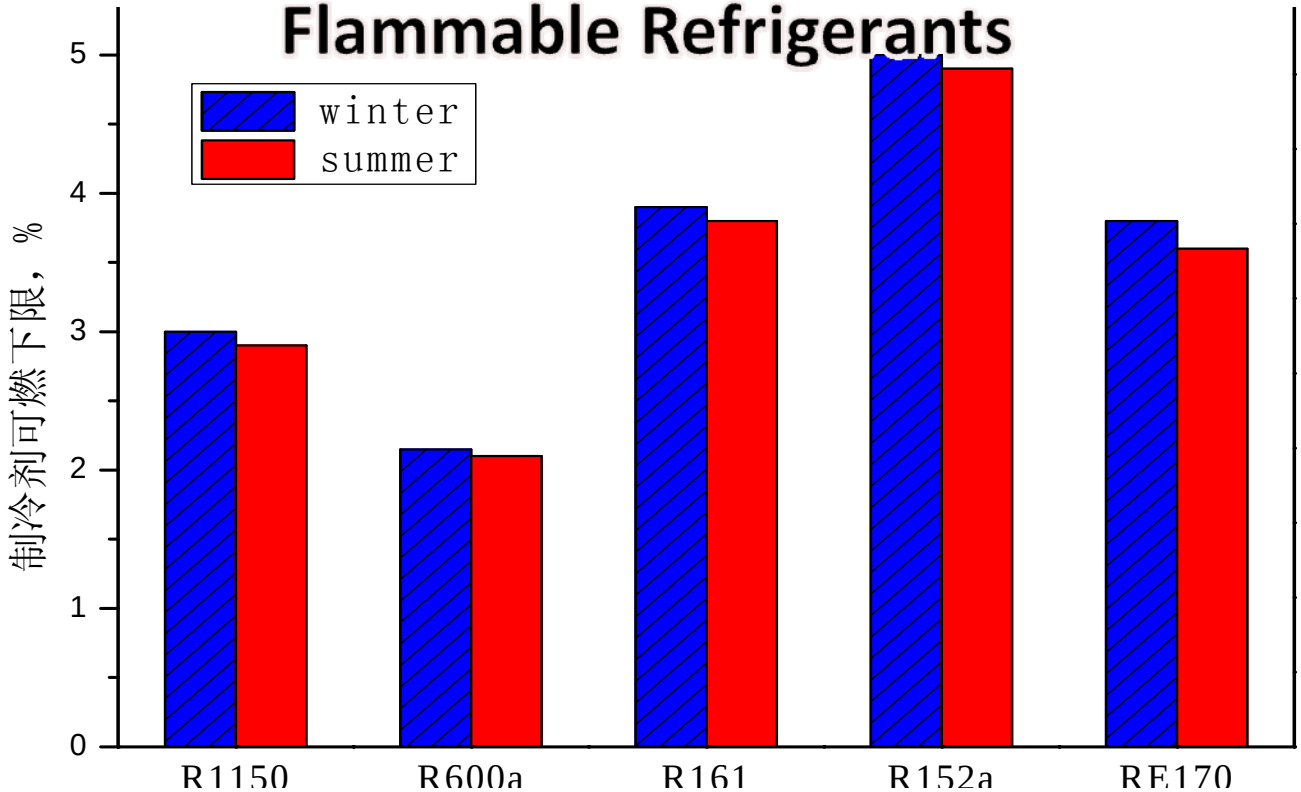


different molecular component shows flame in different colour and shape



The LFL_m of R32 is near to that of the R1234yf, but much higher than that of R290, R600a, R161 and R717.

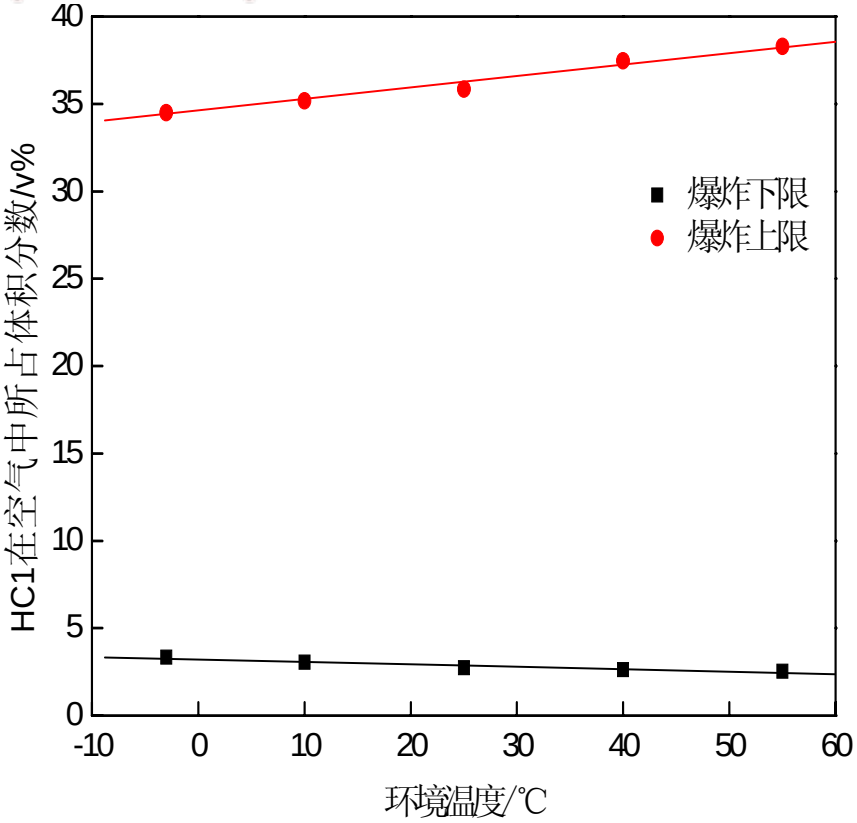
Impact of Temperature on the Flammable Limits of the Flammable Refrigerants



Test Resulis in summer and winter by IERI

Impact of different season on the LFL ,the red one is in summer and the blue one is in winter, so the LFLs decrease with the increase of surrounding air temperature,

Impact of Temperature on the Flammable Limits of the Flammable Refrigerants



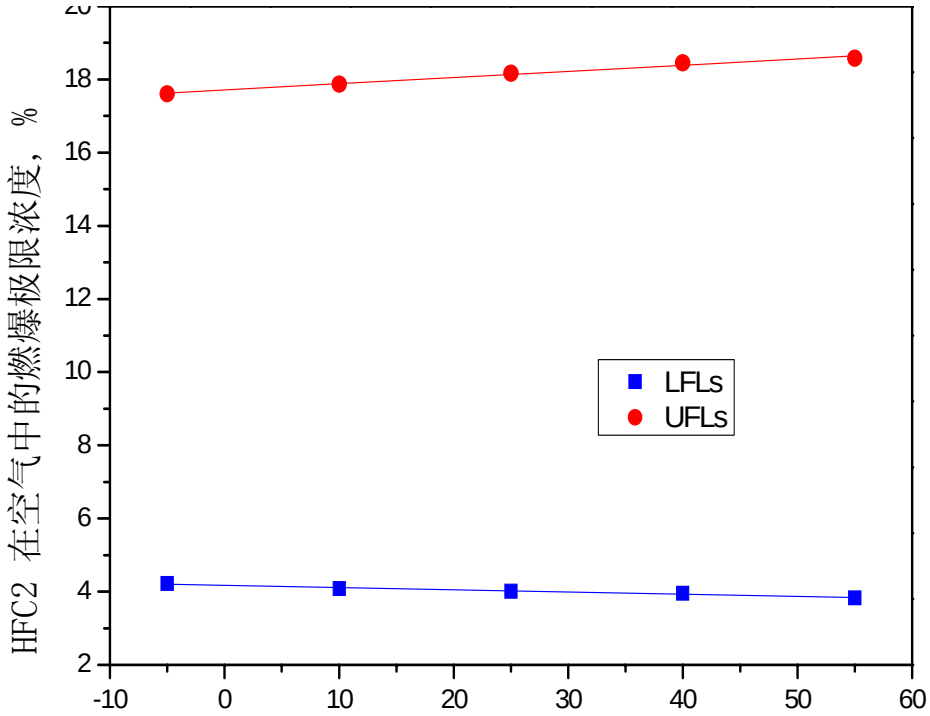


Fig. flammable limits of the HFCs under the variable temperature conditions by TERI

For the two REFs, the LFLs decrease with the increase of surrounding air temperature, and the UFLs increase oppositely as the surrounding air temperature increases from -5 ℃ to 55 ℃,therefore the flammable ranges for this two REFs. will be enlarged with the increase of surrounding air temperature

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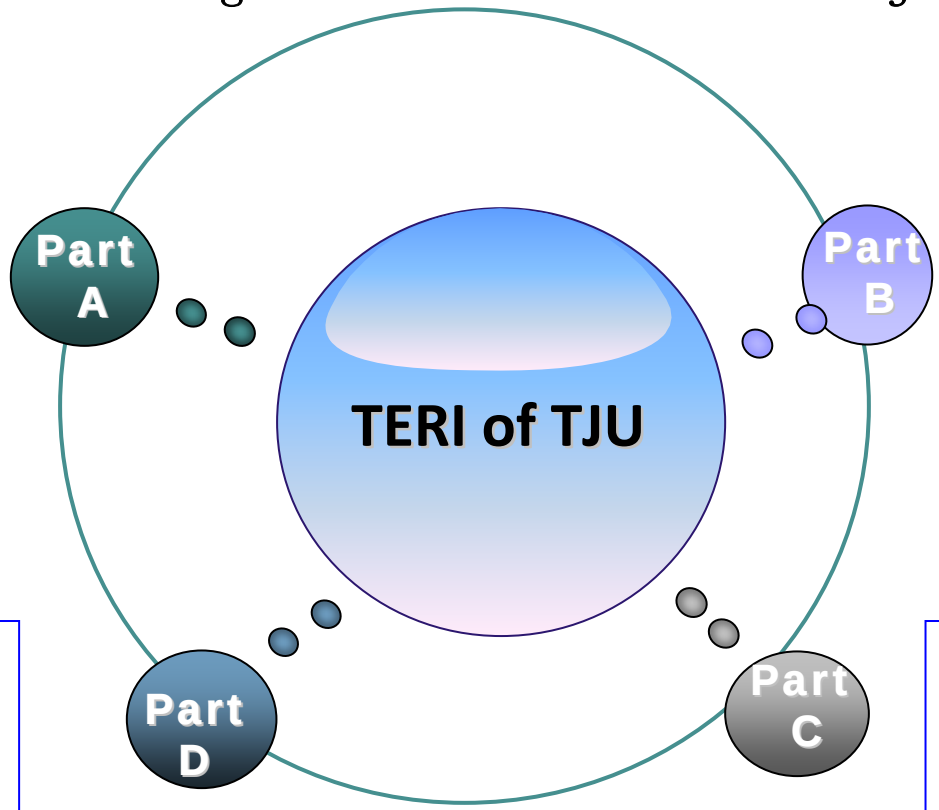
Our research topics on the flammability and safety of lower GWP alternative refrigerants in TERI of Tianjin University

A: Research on the flammable characteristics of new alternatives



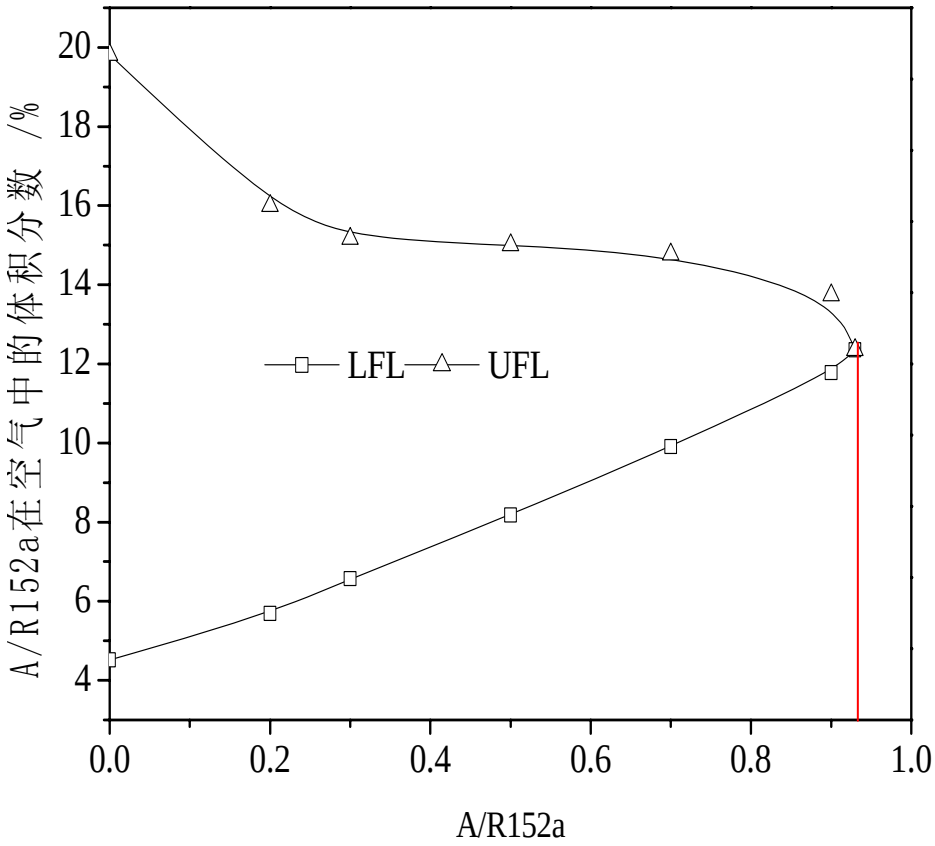
B: Flammability inhibitory technology for combustible refrigerants

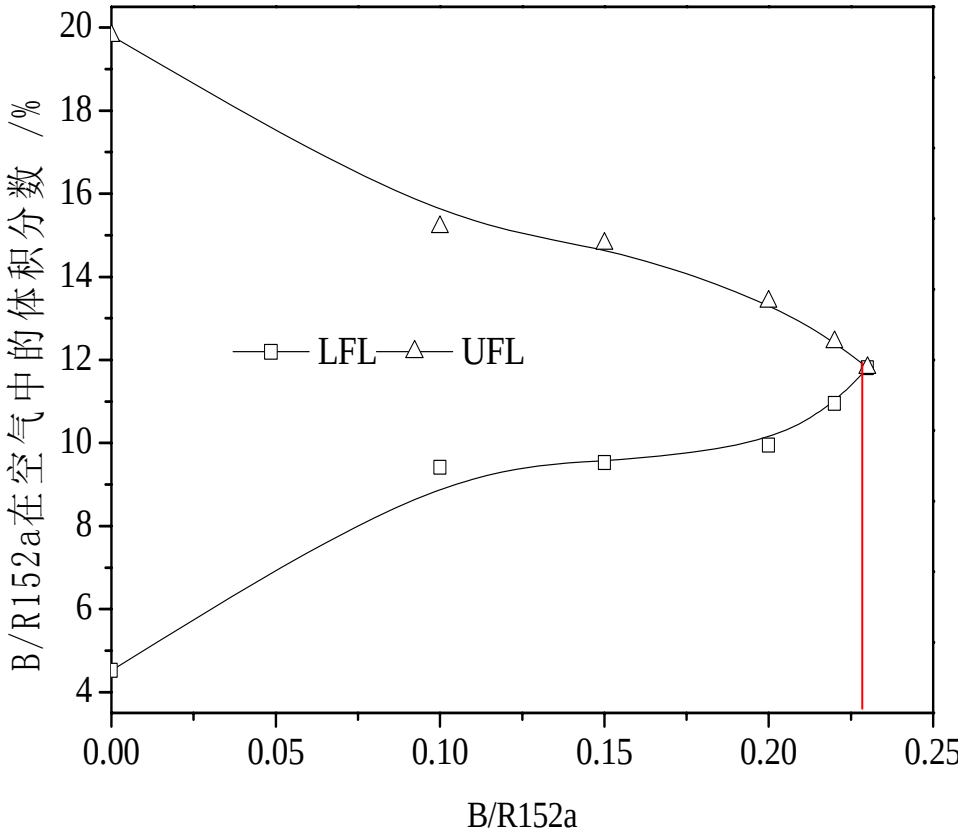
D: Research on the potential fire hazard by leakage

C: Risk assessment to flammable refrigerant system.

There are several research topics on the flammable alternatives that we are engaged in, including A,B,C,D.

Flame retardant efficiency comparison of two inhibitors to R152a by TERI





Some kinds of inhibitors can be mixed with the flammable refrigerant to make the mixture become non-flammable or weak-flammable. This is the LFL and UFL for R152a mixed with A and B.It could reduce the upper flammable limt and increase the LFL.

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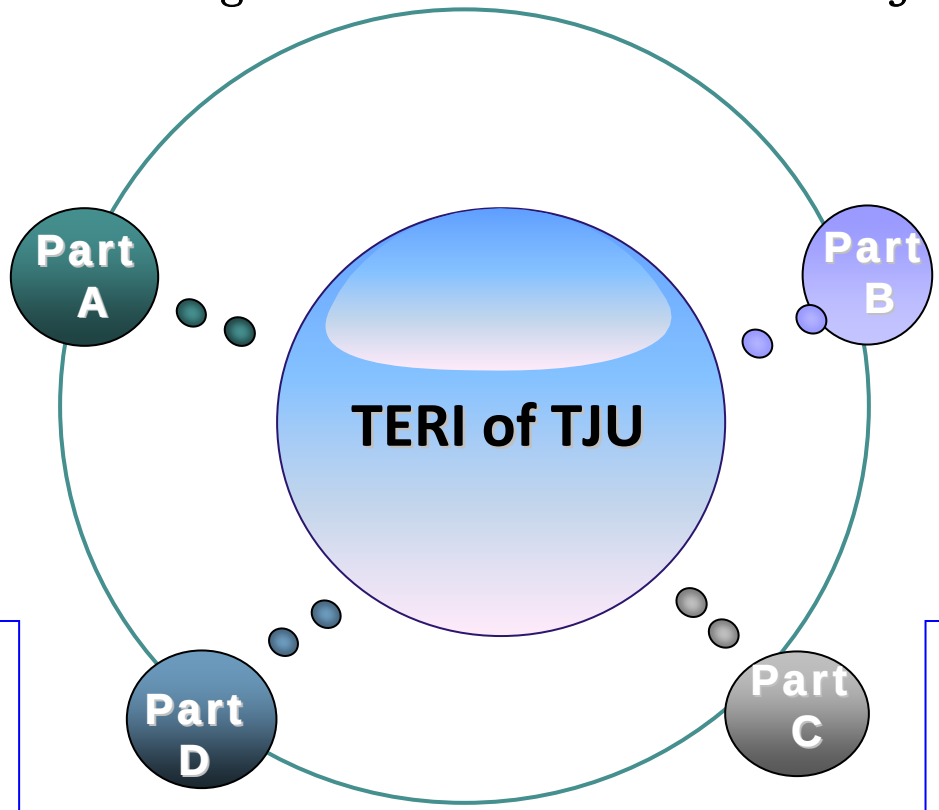

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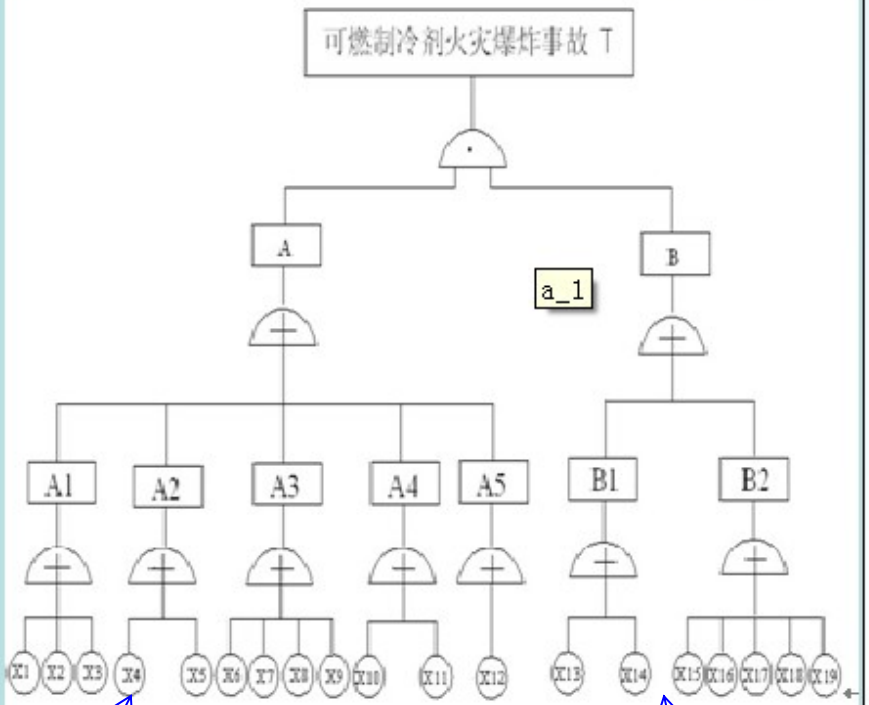
There are several research topics on the flammable alternatives that we are engaged in, including A,B,C,D.

Risk assessment for the units charged with the flammable refrigerant

Possibility



Fault Tree analysis

Consequence

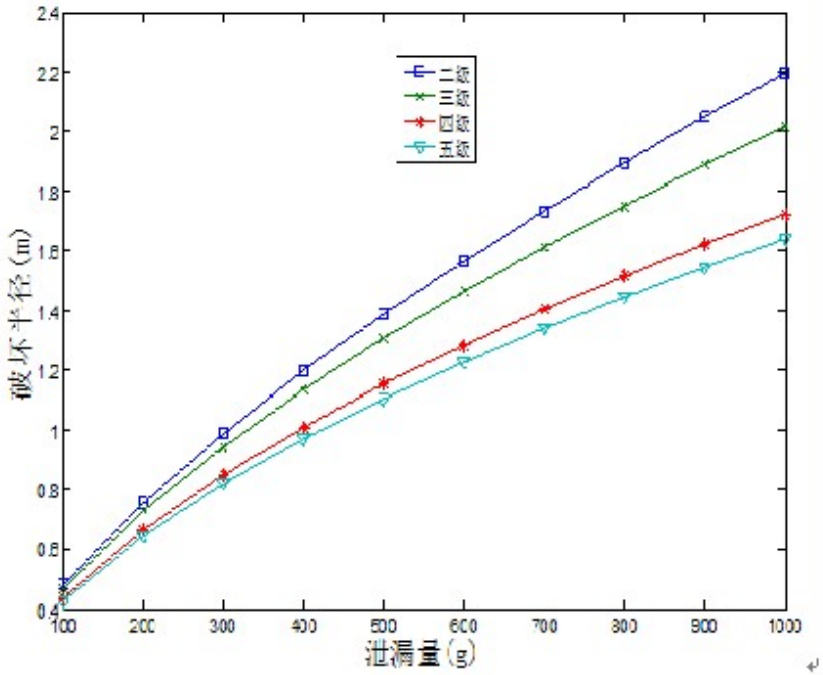


Fig.12 the relationship of HC refrigerant damage radius and leakage

Hazardous area analysis

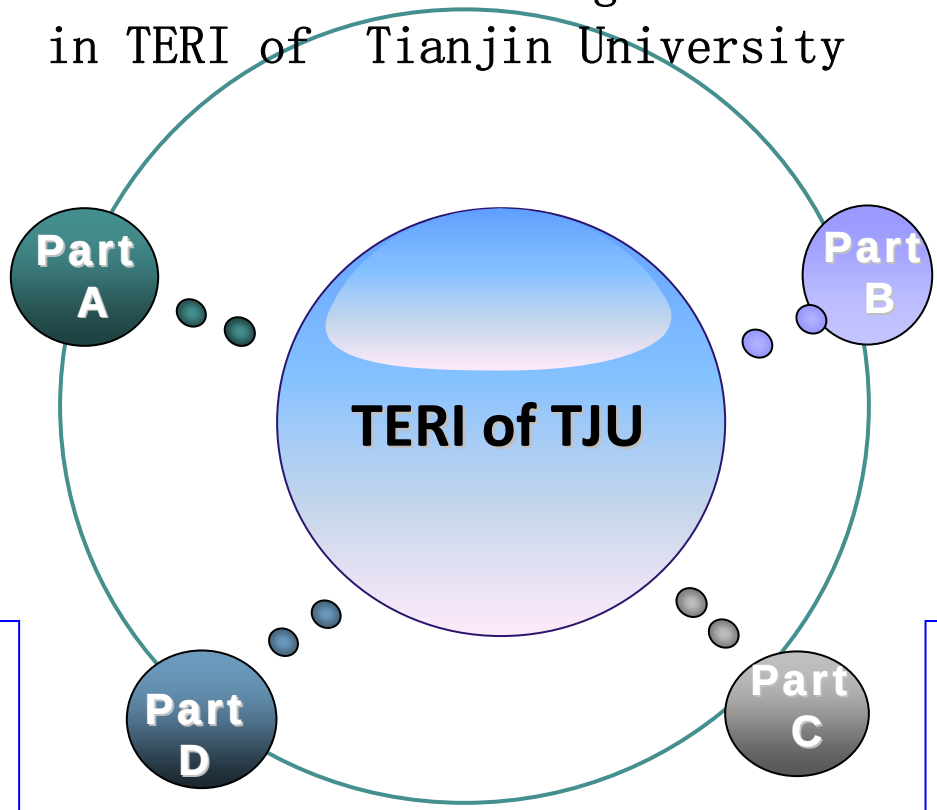
Possibility of leakage

Possibility of ignition sources

fault tree analysis for risk assessment to flammable refrigerant system by TERI

Our research topics on the flammability of lower GWP alternative refrigerants in TERI of Tianjin University

A: Research on the flammable characteristics of new alternatives



B: Flammability inhibitory technology for combustible refrigerants

D: Research on the potential fire hazard by leakage

C: Risk assessment to flammable refrigerant system.

Research on the refrigerant leakage and fire hazardous prevention by TERI

concentration distribution of flammable gases escaping from the air-conditioner by TERI

The higher concentration area of refrigerant locates near the wall below an air conditioner;
The risk can be reduced partly by increasing the outlet wind speed of A/C properly;
Once leakage occurs at the stop model, it is much more dangerous than that of running model .

Experimental Research on the flammability of the lower GWP refrigerants leakaging from the heat pump

A small-sized commercial air source heat pumpwas used to sample at the outlet of compressor at the running model.

Some typical projects on in CHINA

- ***Project on refrigerant converting Freon to hydrocarbon for room air conditioners- by GREE Company***
- ***Demonstration sub-project for conversion of room A/C compressor manufacturing from HCFC-22 to propane –by Guangdong Meizhi Co*.Supported by Multilateral Fund for the Implementation of the Montreal Protocol**
- ***Demonstration sub-project for conversion from HCFC-22 to propane at room air-conditioner -by Midea Manufacturing Company* Supported by Multilateral Fund for the Implementation of the Montreal Protocol**
- **…**

P Han. Ozone2Climate industry roundtable on alternatives to HCFCs, Beijing, Apr.2012

HC290

Application

Production line

Prototype conditioner

Contents

Summary

1\Some standards need to be updated, and some others should be complemented, especially concerning the special requirements on using flammable refrigerants.

2\Related scientific research including risk assessment , flammability inhibitory, simulation and charge reduction technologies sould be continued deeply.

3\flammable limits and burning velocities will be influenced by surrounding air temperature, humidity, ignition energy and lubricant etc.

4\The LFLs of the flammable refrigerants decrease with the increase of surrounding air temperature, and the UFLs increase oppositely, therefore the flammable ranges will be enlarged with the increase of surrounding air temperature.

5\Some kinds of inhibitors can be mixed with the flammable refrigerant to make the mixture become non-flammable or weak-flammable

6\The higher concentration area of refrigerant locates near the wall below the air conditioner; The risk can be reduced partly by increasing the outlet wind speed of A/C properly;Once leakage occurs at the stop model, it is much more dangerous than that of running model.

Note: Some of the details above research could be found on the following published papers in these 3 years:

1.

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Energy

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Review

Retrofits and options for the alternatives to HCFC-22

Zhao Yang*, Xi Wu

School of Mechanical Engineering, Key Laboratory of Efficient Utilization of Low and Medium Grade Energy, MOE, Tianjin University, 92 Weijin Road, Tianjin 30072, PR China

ARTICLE INFO

Article history:
Received 21 December 2012
Received in revised form
22 May 2013
Accepted 24 May 2013
Available online 19 July 2013

Keywords:
R22
Replace
Refrigerant
Flammability

ABSTRACT

HCFC-22, widely used in variety of refrigerating/heating equipment, has been scheduled to be phased out by *Montreal Protocol*. This decision will result in significant reduction of ozone depletion and global warming, holding on the climate benefits accrued so far. In this paper, significant focuses were paid on the HCFC-22 elimination policies, advanced technologies, feasibility substitutes, revolutionary innovations, assessment strategy and developing tendency. The latest developing situation of R744, R717, HC-290, RE170, HFC-32, HFC-161, HFC-152a, HFO-1234yf, HFO-1234ze (E) and their blends were summarized and evaluated technically. Currently there has been no such kind of fluids which can replace HCFC-22 perfectly in most of existing equipment. Many factors must be taken into consideration when selecting an alternative, such as thermodynamic property, environmental impact, system efficiency, technology, flammability, toxicity, cost, policy etc., which can be regarded as a multi-objective decision problem. It is predicted to be increasingly important to research the flammable characteristics of re-

2.

Contents lists available at ScienceDirect

Process Safety and Environmental Protection

journal homepage: www.elsevier.com/locate/psep

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IChemE

Experimental research on the flammability characteristics of several binary blends consisting of 1-Chloro-1,1-difluoroethane and extinguishing agents

Xi Wu[a,b], Zhao Yang[a,b,*], Tian Tian[a,b], Mengxue Qin[b]

[a] State Key Laboratory of Engines, Tianjin University, 92 Weijin Road, Tianjin, 300072, PR China
[b] Key Laboratory of Efficient Utilization of Low and Medium Grade Energy, MOE, School of Mechanical Engineering, Tianjin University, 92 Weijin Road, Tianjin, 300072, PR China

ABSTRACT

3.

Energy 52 (2013) 185–191

Contents lists available at SciVerse ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

ELSEVIER

Experimental and theoretical study on the influence of temperature and humidity on the flammability limits of ethylene (R1150)

Xi Wu, Zhao Yang*, Xiaoming Wang, Yulong Lin

School of Mechanical Engineering, Key Laboratory of Efficient Utilization of Low and Medium Grade Energy, MOE, Tianjin University, 92 Weijin Road, Tianjin, 30072, PR China

ARTICLE INFO

Article history:
Received 11 July 2012
Received in revised form
21 January 2013
Accepted 22 January 2013
Available online 21 February 2013

ABSTRACT

The LFL (lower flammable limit) and UFL (upper flammable limit) of R1150 were researched experimentally on a self-made test rig according to the Chinese National Standard GB/T12474 under variable temperature and humidity conditions. Results showed that the LFL increased with the decrease of temperature, while the UFL reduced, therefore the flammable range shrank 3.42% from 55 °C to −5 °C. Another group of experiments had been carried out to test the influence of humidity on the flammable limits of R1150 at 25 °C,

4.

INTERNATIONAL JOURNAL OF REFRIGERATION 36 (2013) 1483–1494

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journal homepage: www.elsevier.com/locate/ijrefrig

Research on the flammability hazards of an air conditioner using refrigerant R-290

CrossMark

Wang Zhang [a,b,*], *Zhao Yang* [a], *Jin Li* [b], *Chang-xing Ren* [b], *Dong Lv* [b], *Jie Wang* [b], *Xin Zhang* [b], *Wei Wu* [b]

[a] *School of Mechanical Engineering, Tianjin University, 92 Weijin Road, Tianjin 300072, PR China*
[b] *Tianjin Fire Research Institute of MPS, No. 110 Weijinnan Road, Tianjin 300381, PR China*

ARTICLE INFO

Article history:
Received 16 November 2012

ABSTRACT

Currently, hydrochlorofluorocarbons and hydrofluorocarbons are the most common refrigerants used for air conditioners. Due to ozone depletion and high global warming po-

5.

flame-retarding characteristic.pdf - Adobe Reader

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Experimental Thermal and Fluid Science 44 (2013) 613–619

Contents lists available at SciVerse ScienceDirect

Experimental Thermal and Fluid Science

journal homepage: www.elsevier.com/locate/etfs

Theoretical and experimental investigation on the flame-retarding characteristic of R245fa

Zhao Yang *, Xi Wu, Jijun Peng

Key Laboratory of Efficient Utilization of Low and Medium Grade Energy, MOE, School of Mechanical Engineering, Tianjin University, 92 Weijin Road, 300072 Tianjin, P.R. China

ARTICLE INFO

Article history:
Received 17 May 2010

ABSTRACT

Some binary mixtures comprised of R245fa and flammable refrigerant were expected to be a drop-in

29% 0.2K/s 0K/s

20:53
2015-07-24

6.

INTERNATIONAL JOURNAL OF REFRIGERATION 56 (2015) 235–245

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Research on the flammable characteristics of fluoroethane (R161) and its binary blends

CrossMark

Zhao Yang [a,b,*], Xi Wu [a,b], Xiaoming Wang [a,b], Tian Tian [a,b]

[a] State Key Laboratory of Engines, Tianjin University, 92 Weijin Road, Tianjin 300072, PR China
[b] Key Laboratory of Efficient Utilization of Low and Medium Grade Energy, MOE, School of Mechanical Engineering, Tianjin University, 92 Weijin Road, Tianjin 300072, PR China

ARTICLE INFO ABSTRACT

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