Counter Argument against Propane Proponent

DAIKIN INDUSTRIES, LTD.

Contents

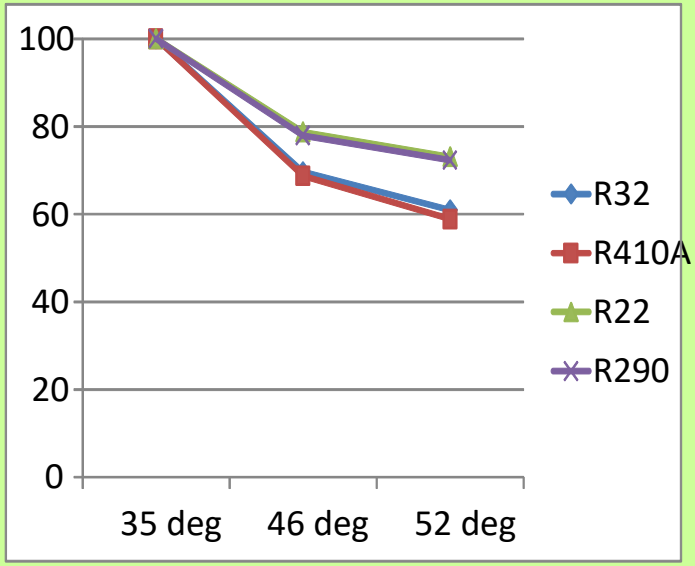
- Energy Efficiency
- Safety
- Total Evaluation

Energy Efficiency-Consumption

Propane Proponent

A) Propane's energy efficiency is better than R22.

B) Propane's efficiency drop is less even under high ambient temperature.



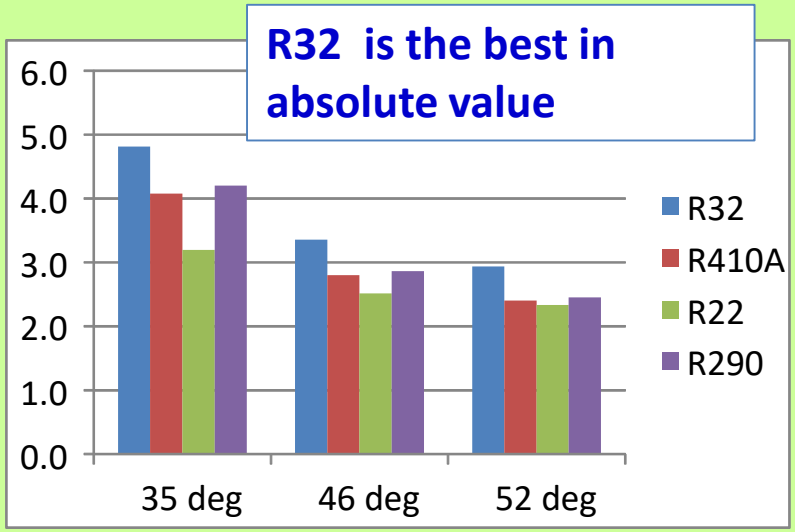
TRUTH

A) R290 has better efficiency than R22 in drop-in testing.

B) R410A and R32 **CANNOT drop-in to R22** units due to different oil and pressure

C) When capacity is same, **COP of R32 is better than R290**.

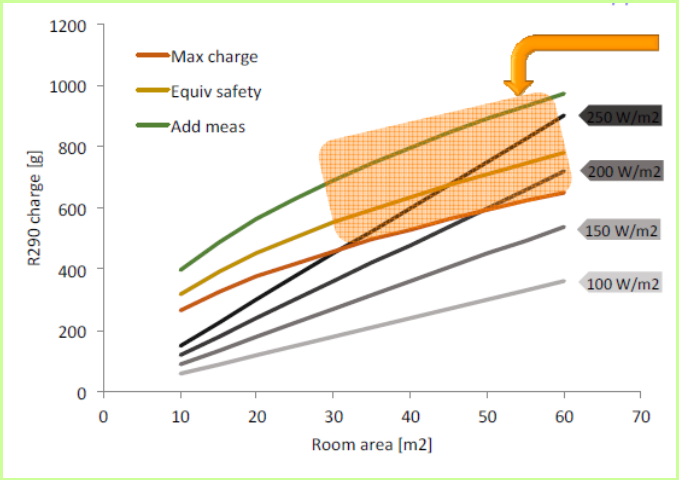
D) If optimized, **the COP of 32 will increase another 1%** and more.



Energy Efficiency-Charge Volume

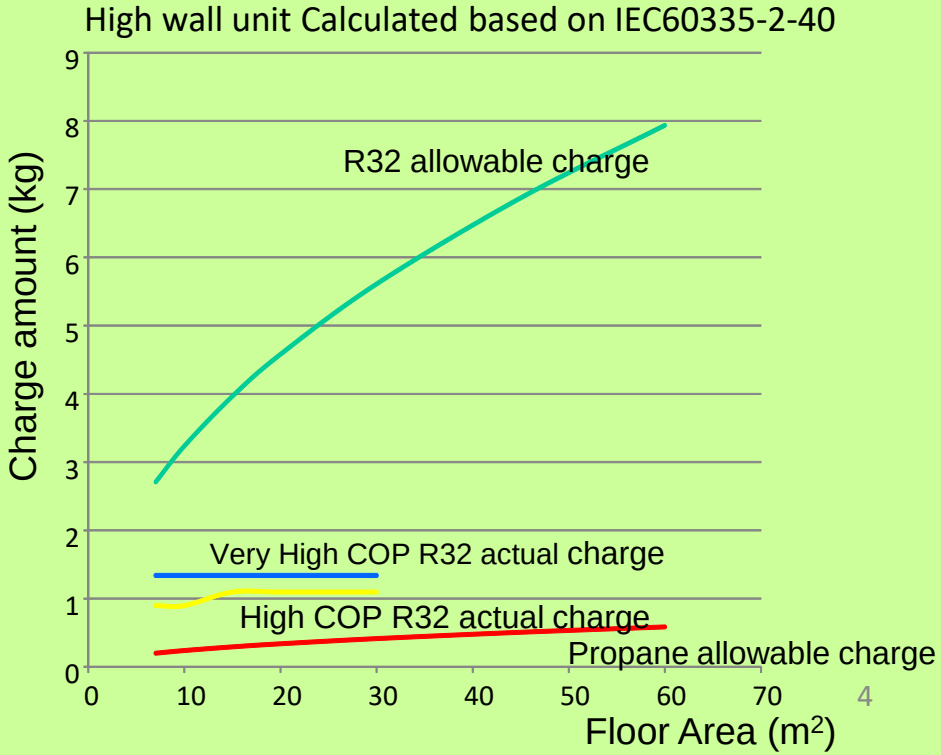
Propane Proponent

- Based on new SAC designs – low charge, high efficiency products, most applications achieved.



TRUTH

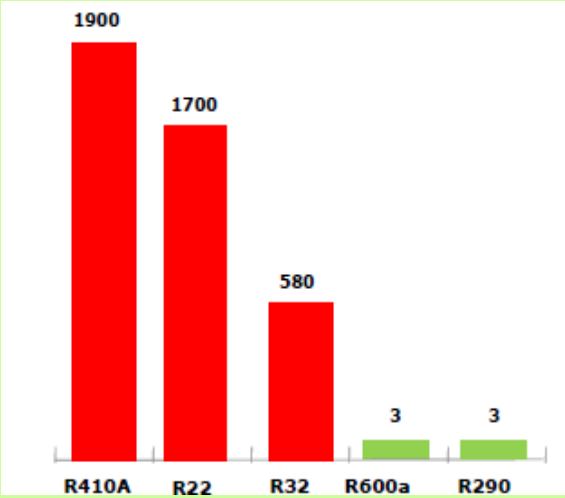
- R290's charge volume is strictly limited due to very low LFL, while energy efficiency regulation generally requires higher charge in larger heat exchanger.
- So**, in reality, heat exchanger of dedicated R290 unit optimized for safety does not perform well in most cases.**



Energy Efficiency- Life Cycle Climate Performance (LCCP)

Propane Proponent

GWP is the most important .

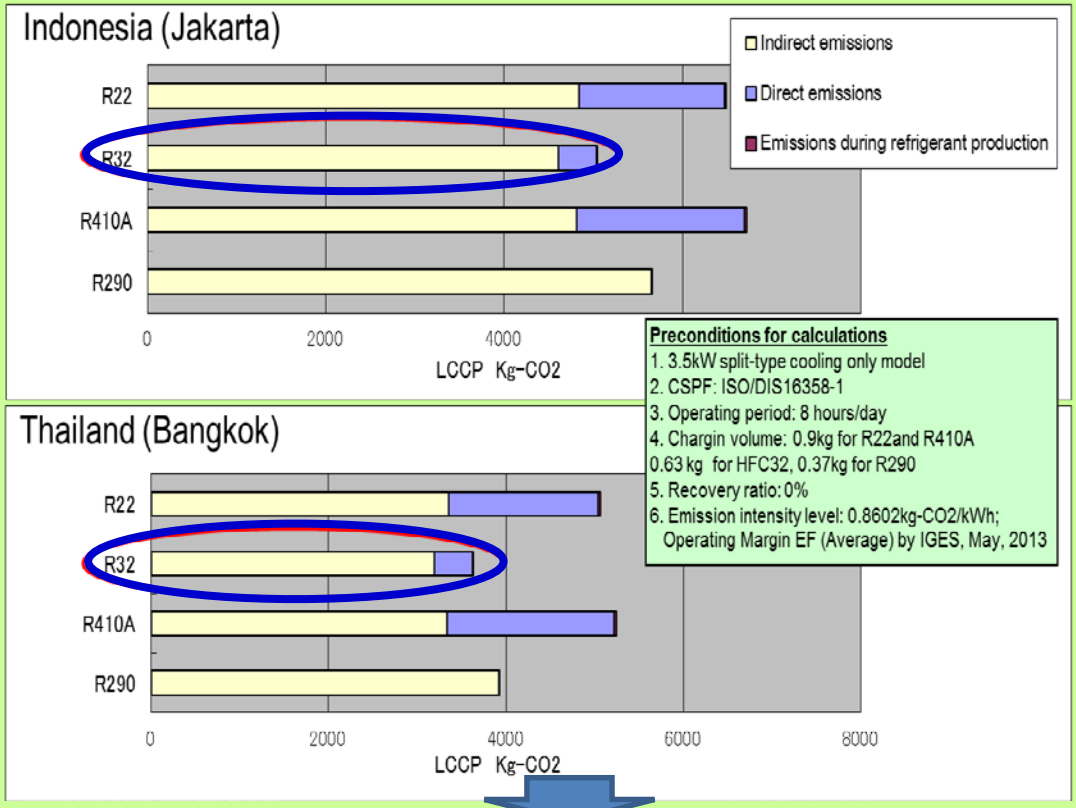


Refrigerant	Molecular	GWP	ODP
R290	C_3H_8	3	0
R32	CH_2F_2	580	0
R410A	R32/R125	1900	0
R22	CHF_2Cl	1700	0.055

TRUTH

Yes. GWP of R290 is low.
To mitigate **the global warming impact, total evaluation is the most important, not only GWP**.
80-90% of CO2 comes from energy consumption.
Energy efficiency matters.

- LCCP Comparison 3.5 kW Room AC (Cooling Only Model)



R32 has the best LCCP in shown refrigerants.

Safety - Flammability Classification

Propane Proponent

Propane and R32 are both flammable as if they are in the same flammability level.

Both R290 and R32 are classified as flammable

		R290	R32	R22	R410A	R134a
LFL	vol%	2.1	13.5	NA	NA	NA
	kg/m³	0.038	0.306	NA	NA	NA
AIT	℃	470	648	635	N.D.	743
MIE	mJ	0.31	30-100	NA	NA	NA
BV	cm/s	46	6.7	NA	NA	NA
HOC	MJ/kg	50.3	9.4	2.2	-4.4	4.2
OEL	PPMv	1000	1000	1000	1000	1000
Safety(ASHRAE34)		A3	A2L	A1	A1	A1

LFL: under 23℃, 101.3kPa.

TRUTH

Half yes. But the flammability level is significantly different.

Propane can be easily ignited by even static electricity of human body.

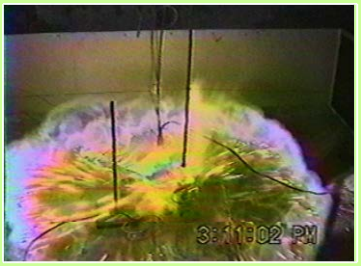
Note: Static electricity: Refer to the next page

Increasing hazard →

Classification of refrigerants – ISO 817 (2014)	Lower toxicity	Higher toxicity
Higher flammability	A3	B3
Flammable	A2	B2
Lower flammability	A2L	B2L
No flame propagation	A1	B1

↑ Increasing hazard

Propane=Higher Flammability



R32=Lower Flammability

■Flammability Issue of Refrigerant

Reference

- Trade Off relation between GWP and Flammability
- Unavoidable physical and chemical phenomena

Reference

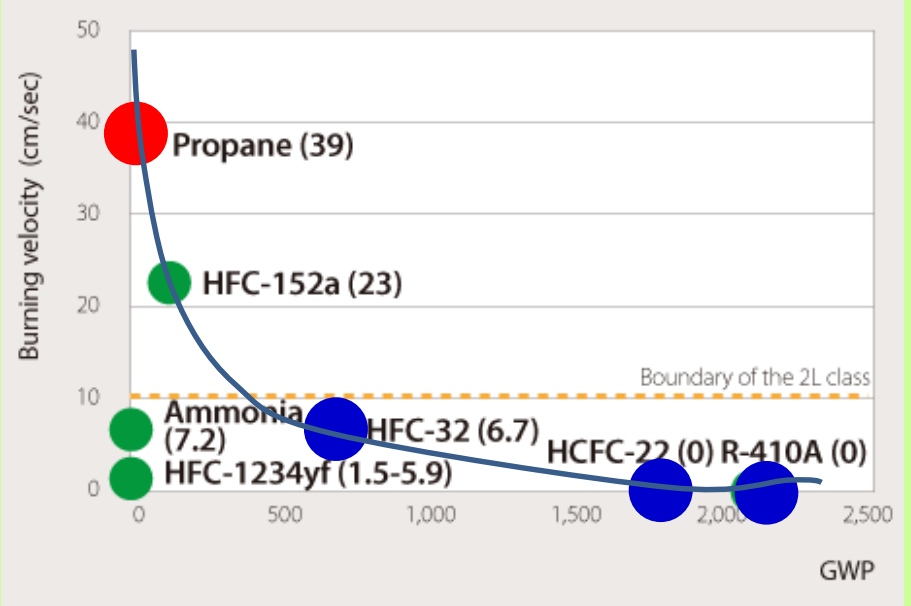
How easy to ignite R290

R290 can easily be ignited with static electricity of human body, although R32 cannot. **R290 easily explodes since its burning velocity is too fast** while **R32 does not explode since its burning velocity is too slow**.

- Required MIE(minimum ignition energy) to ignite gases (refrigerants).

	MIE [mJ]	LFL [vol%]	UFL [vol%]
Propane	0.25	2.1	10
Butane	0.29	1.8	8.4
Isobutene	?	1.8	8.4
R152a	0.38	3.9	16.9
Methane	0.47	5	16
R32	>30, <100	14.4	29.3
NH3	>100, <300	15	28
HFO1234yf	>1000	6.5	12.3

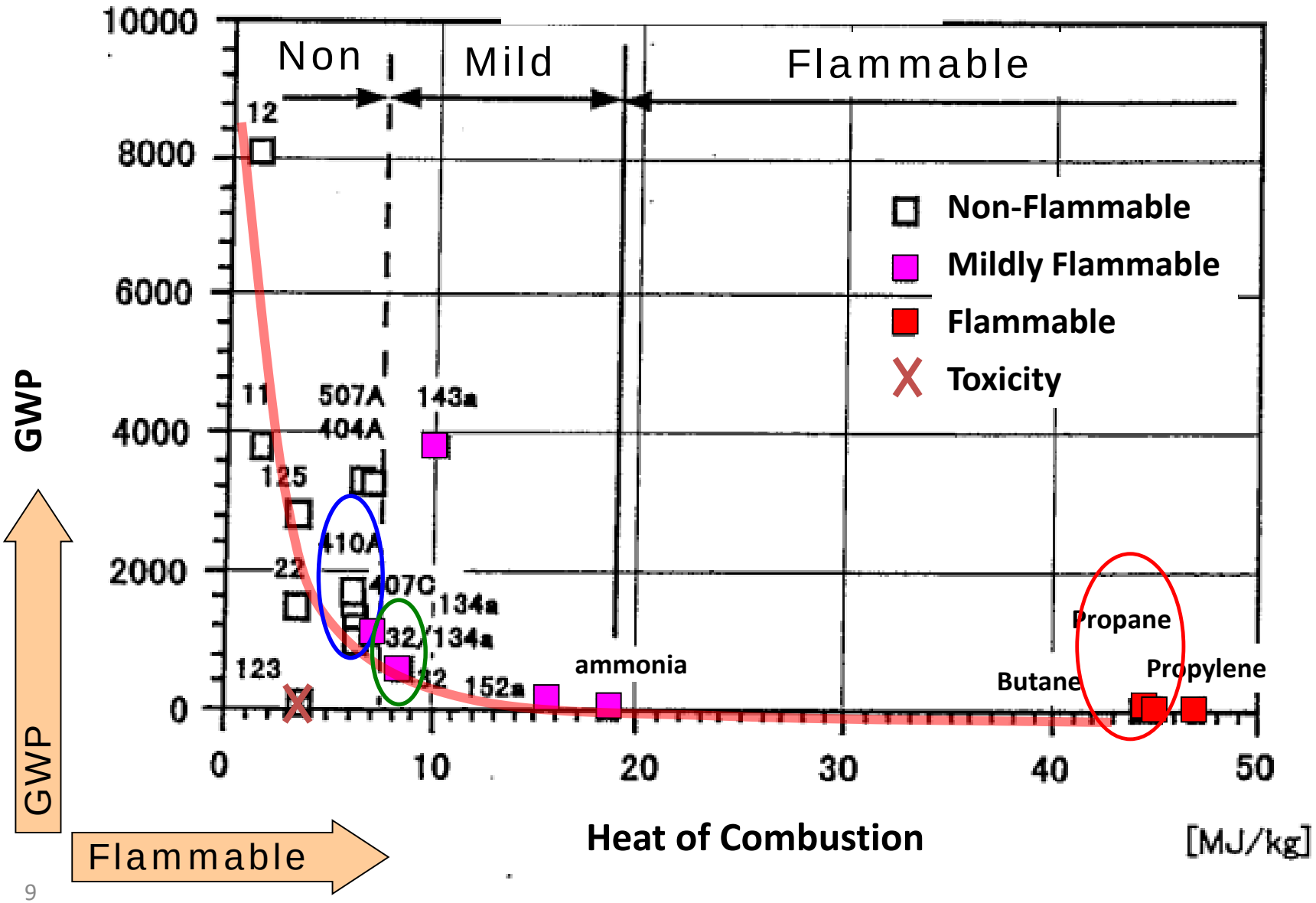
- Relationship between Burning Velocity and GWP



BV is indicated in parentheses.
Source: Japan Refrigeration and Air Conditioning Industry Association (JRAIA)
Risk Assessment of Mildly Flammable Refrigerants 2013 Progress Report, April 2014, The Japan Society of Refrigerating and Air Conditioning Engineers

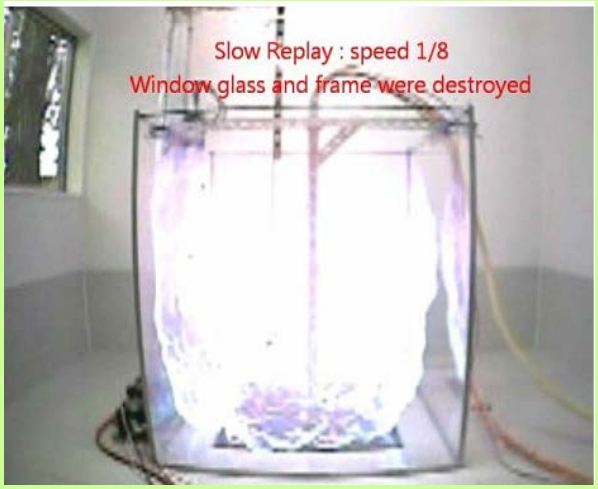
Risk Tradeoff of refrigerant

Reference



■Ignition Test for Extreme Condition

Reference



R290(propane)
30g in 1m cubic box

Exploded by electric spark

R32
320g in 1m cubic box

Ignited by open flame

R1234yf
180g in 1m cubic box

Ignited by open flame

Class 3
Higher flammable

Class 2L
Slightly flammable

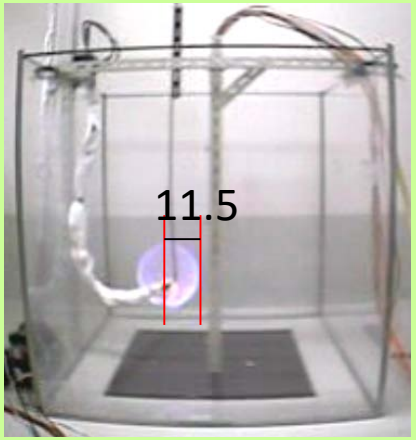
■Flame Propagation of Propane

Reference

- ☐ Refrigerant Volume=**30g** (LFL= 2.1 v/v%)
- ☐ Ignition Source: **Electric Spark** (Descending Speed 5cm/sec)
- ☐ Size of Box：1m*1m*1m


0


1

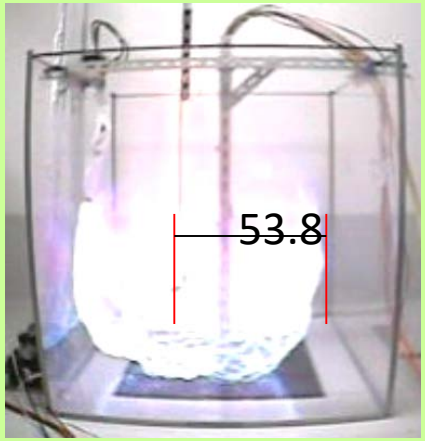


2


3


4


5



6

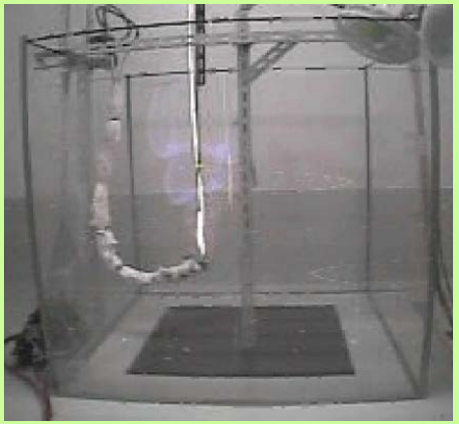

10

■Flame Propagation of R32

Reference

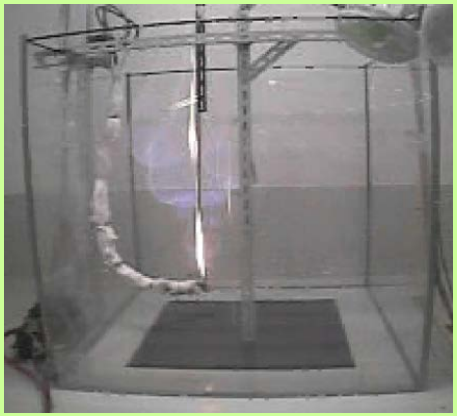
- □ Refrigerant Volume =**320g** (LFL=14.1 v/v%)
- □ Ignition Source：**Pilot Burner**（(Descending Speed 5cm/sec）
- □ Box Size：1m*1m*1m



コマ数　0　87　140　186

（30コマ/sec）

222　245　502　532

（種火消化後10）

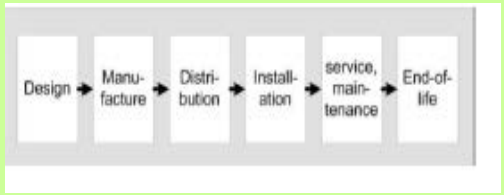
Safety - Capacity Building

Propane Proponent

Propane is safe because engineers are sufficiently trained.

GIZ handbook: Comprehensive overview over safety requirements as basis for capacity building measures

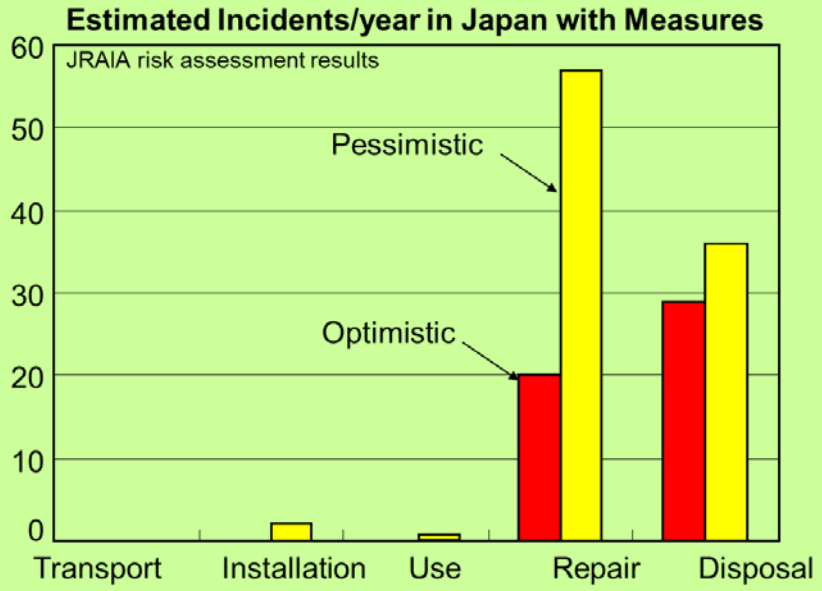
- Safety infrastructure
- Quality system for safety
- Training
- Production and manufacturing
- Equipment design and development
- Working on systems



TRUTH

Propane can be safe if installers are perfect. However, according to assessment by JRAIA says that repair and disposal risks are considerably high even after measures are taken.

These are due to **human error**, hard to reduce.



Refer to the accidents list in the following pages

■Accident example of Hydrocarbon Refrigerant

Reference

	Type	Refrigerant	Place/Date	Detail of accident
1	Refrigeration	Propane	New Zealand 2008/4/5	**Propane Refrigerant leaked and massive explosion occurred** in cold storage, **killed one fireman and injured seven**. Refrigeration units originally charged with HCFC-22 was replaced with propane.
2	Refrigeration	Propane	New Zealand 2010/5	**Propane was exploded during welding work.** Markings on the valve he was repairing and other parts of system indicated it contained non-flammable R22 or Freon.
3	AC	HR429 or neat Propane	Hong Kong 2013/1/9	**During maintenance, AC was exploded.** Witnesses at the time said they heard two explosions which smashed all the windows in the second floor restaurant. **More than 20 people were injured**.

Accident example of Hydrocarbon Refrigerant

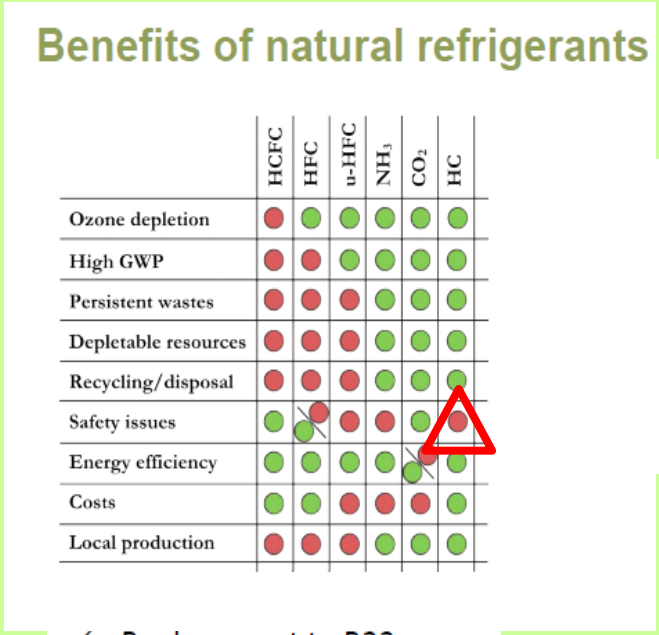
Reference

	Type	Refrigerant	Place/Date	Detail of accident
4	AC	HC	Singapore	**During servicemen's decommissioning work, flash fire was occurred.** Resulting in **one fatality** and **two workers injured.**
5	AHU	HC	Singapore	**HC refrigerant leaked from an AHU during normal operation** and **resulted in a flash fire**.
6	Mobile AC	Highly flammable/ non-standard refrigerants	Australia 2014/5/8	**Two vehicle occupants seriously injured by fireball** linked to air-con refrigerant leak.
7	Tank	Liquid propane	USA	**Liquid propane explosion occurred by refrigerant charging work by unskilled person.** Resulting in the **death of two emergency responders and two propane service technicians, and injured six others.**

Total Evaluation

Propane Proponent

Propane is the best solution except for flammability.



- ✓ Replacement to R22
- ✓ Good energy performance
- ✓ Low GWP
- ✓ No persistant waste
- ✓ Low costs
- ✓ Can be produced locally

TRUTH

To make sure of safety, **significant cost increase is conceivable such as safe development and designing, training, and disposal. Flammability is the most important factor to evaluate.**