Safety concerns for A2L refrigerants in AC service procedures

“Alternative Refrigerants for High-Ambient Countries; Risk Assessment of Future Refrigerants in Production, Installation, and Service”

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Dubai

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JRAIA

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- This presentation has been made based on the latest technical information as accurate as possible.
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1. Introduction

- JRAIA is the HVAC&R industry association basically consists of equipment manufacturers in Japan.
- Full members are 75 and associate members are 47 including major players of;
  - Daikin, Fujitsu-General, Hitachi, Mitsubishi Electric, Mitsubishi Heavy Industry, Panasonic, Toshiba-Carrier
- Mission of JRAIA are;
  - Promotion and Improvement of the HVAC&R Industry, Products and Components
- Japanese market in is around 8.5 million residential AC/HP and 0.8 million commercial AC/HP per year.

2.1 JRAIA Risk assessment

- Joint projects of Japanese academia and industry for A2L refrigerants are ongoing.
- The progress report of the projects can be found in http://www.jsrae.or.jp/jsrae/committee/binensei/risk_e.html
- Pretty much important information can be found.
- Presentations of the projects will be made at JRAIA Symposium in Kobe on November 20 - 21, 2014 at International Conference Center Kobe. Key results of the projects will be presented. Details of the event are; http://www.jraia.or.jp/symposium/index.html
- In Japan, a few to several millions of residential mini-splits have been sold with R32, but no accident has been reported.

2.2 Service procedure and risk

- The risk assessment indicates relatively high risk in service, installation, disposal, and use of outdoor unit.
- Key concern in service procedures are;
  - Accidental release and existing ignition source
  - Brazing /welding process
  - Tools (vacuum pump and refrigerant recovery comp.)
  - Smoking of service person? (Effectiveness of training)

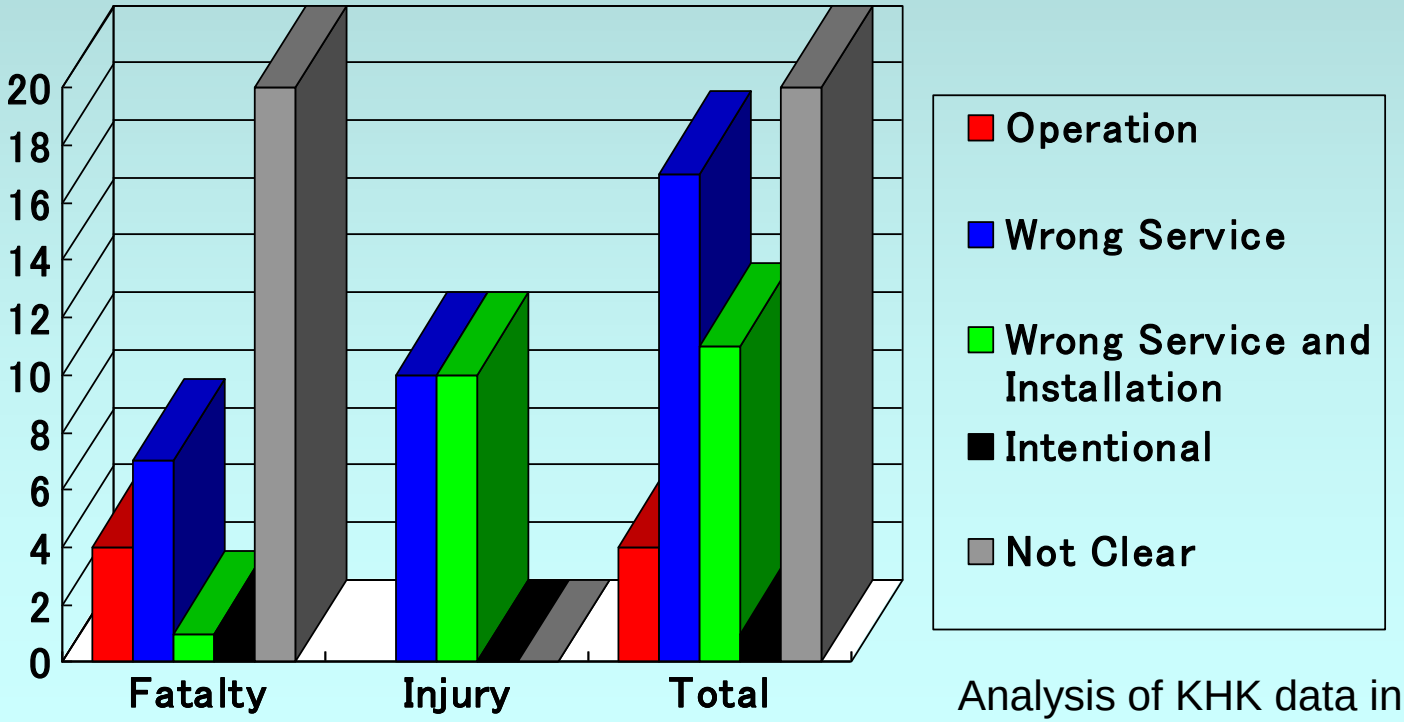
Table 8.1.3 Results of risk assessment review

Risk: Ignition Probability			
	R290	R32	R1234yf
Logistic	9.2×10^{-11}–1.4×10^{-7}	4.1×10^{-12}	4.5×10^{-12}
Installation	3.7×10^{-9}–2.2×10^{-8}	2.7×10^{-10}	3.1×10^{-10}
Use (Indoor)	5.0×10^{-13}–9.5×10^{-9}	3.9×10^{-15}	4.3×10^{-15}
(Outdoor)	4.9×10^{-13}–9.3×10^{-9}	1.5×10^{-10}	2.1×10^{-10}
Service	2.8×10^{-7}–8.1×10^{-7}	3.2×10^{-10}	3.6×10^{-10}
disposal	4.1×10^{-7}–5.1×10^{-7}	3.6×10^{-11}	5.3×10^{-11}

The risk assessment results of mini-split from the progress report

2.3 Cause of accidents in Japan

- Statistics also indicates one of major cause of refrigerant sudden release accidents are errors in service.
- Major sudden release has to be considered during and just after services.



Analysis of KHK data in 1998..

CFC, HCFC toxicity accidents

3.1 A2L Flammability

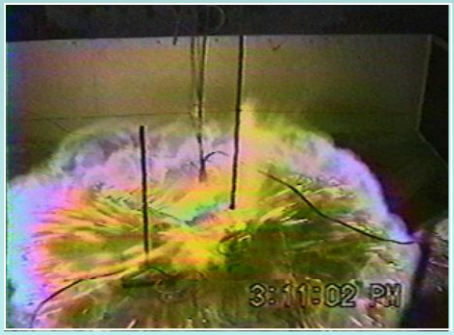
- Historically, ammonia has been exempted from “flammable gas requirements” in many standards or regulations, although it is flammable.
- Class 2L was originally proposed to express ammonia flammability more precisely and to extend its exemptions.
- Burning velocity was chosen to classify 2L refrigerants in ISO817 and ASHRAE 34. Conventional indices are not effective.

	BV (m/s)
Hydrogen	2.91
Ethylene	0.75
CO	0.11-0.43
Propane	0.43
Iso-Butane	0.38
Methane	0.37
R152a	0.23
Ammonia	0.07
R143a	0.07
R32	0.07
R1234yf	0.02-0.06
R22, R410A	-

The data reported by Ecole des Mines or quoted from the combustion textbooks.

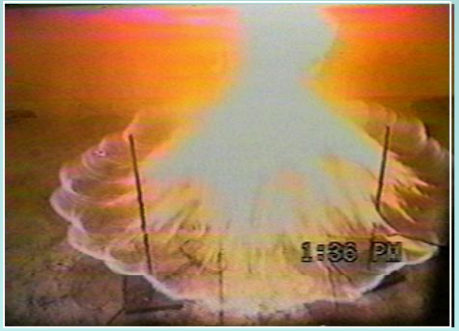
3.2 Practical combustion of 2L

- Refrigerants in 2L class burns slowly even stagnated conditions and do not Flash and hard to ignite when flowing.
- Flammability of 2L is far less than lubricant and brazing gas.



Propane

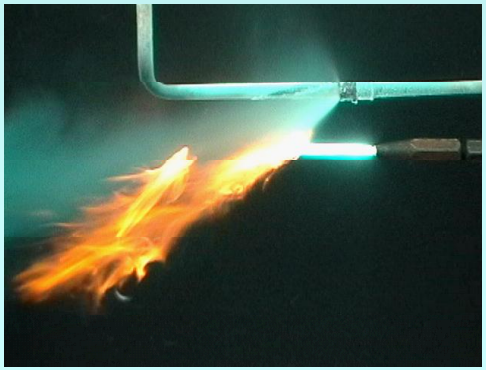
Ammonia



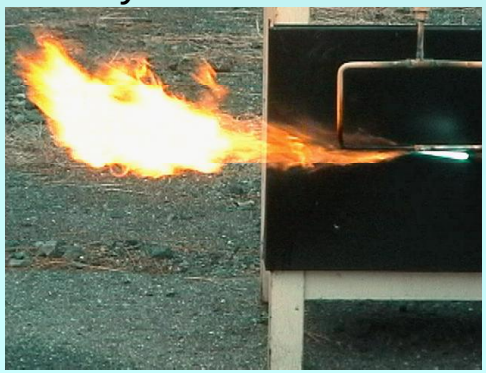
R152a

R32

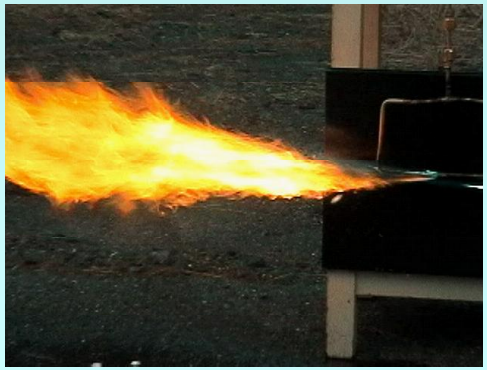
These tests are carried out by Factory Mutual Research Center in the US in 1996.



R32



R32+Ether oil



R22+Mineral Oil

3.3 Real risk in brazing

- If we see the flames in the same scale, the difference is clear.
- Mineral oil has lower surface tension, resulting in fine mist and large flame.
- A2Ls have much smaller combustion energy per mass than lubricant.

R32 **R32+Ether oil** **R22+Mineral Oil**

The tests are carried out by Daikin and presented in the JRAIA Kobe Symposium 2000

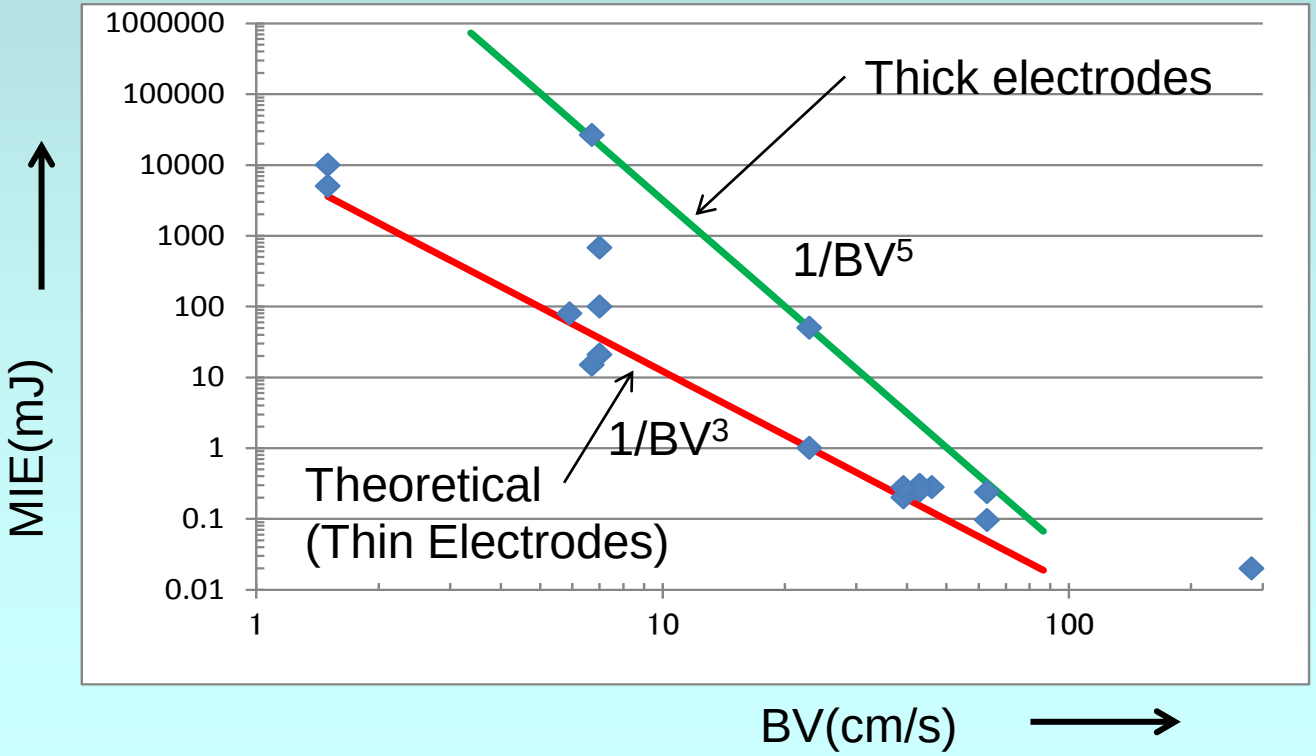
3.4 Open flame ignition

- Combusting gas flame does not spread to leaking 2L refrigerant except ammonia, as convection velocity is higher than BV.
- However, candle can ignite 2L.

The tests are carried out by Daikin.

3.5 Minimum Ignition Energy (MIE)

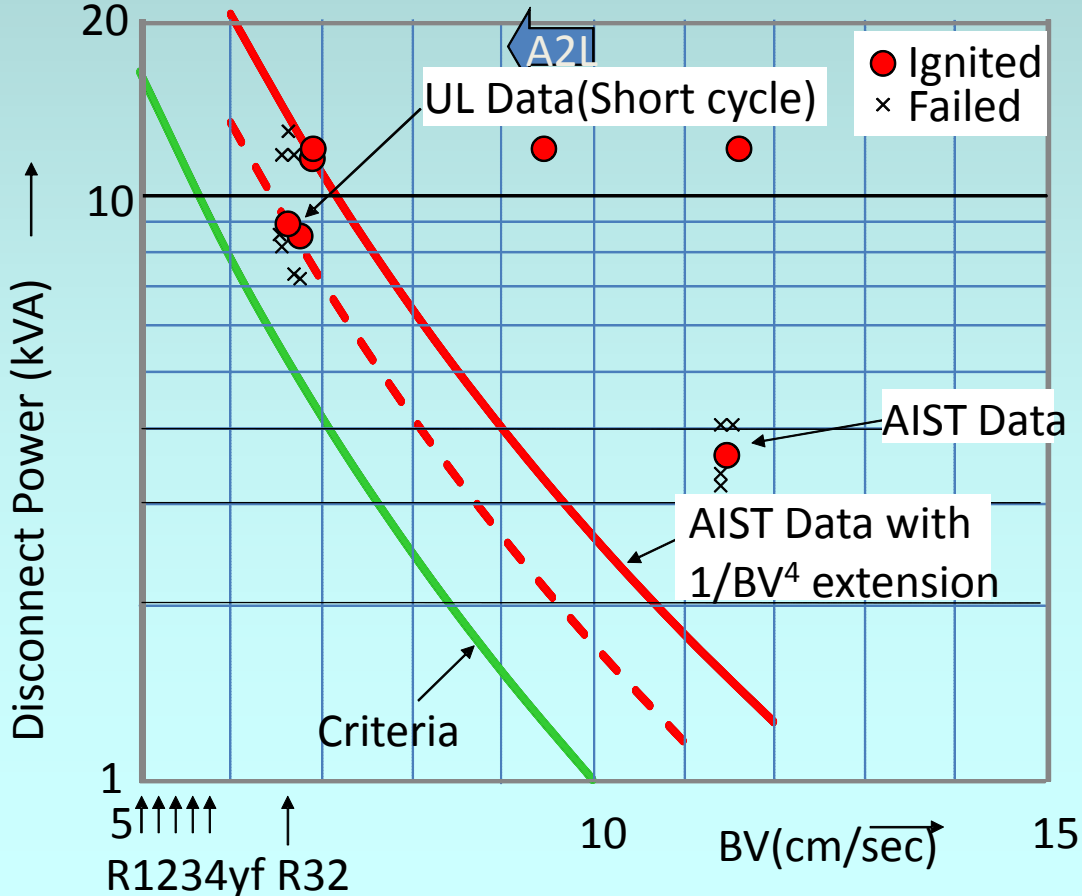
- MIE is dominated by burning velocity basically.
- Quenching effect of electrode significantly affects MIE with low burning velocity substances.
- BV affects probability of ignition significantly.



The data are measured by Dr. Takizawa :AIST and are quoted from quoted from various published literature.

3.6 Relay test results

- Large power disconnection is necessary to ignite A2L with BV<8 cm/s but 10 cm/s? IEC WG9 agreed the criteria 3 ϕ 5kVA and 1ϕ 2.5 kVA for R32.
- Most portable service tools have power below the criteria.



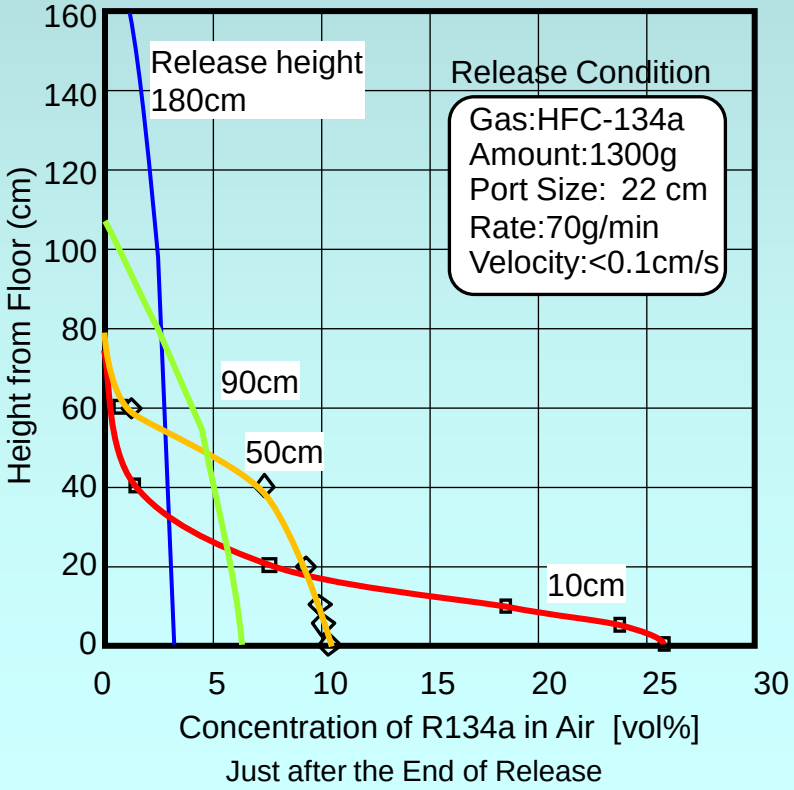
The data are measured by Dr. Takizawa :AIST and are quoted from AHRI report measured by UL.

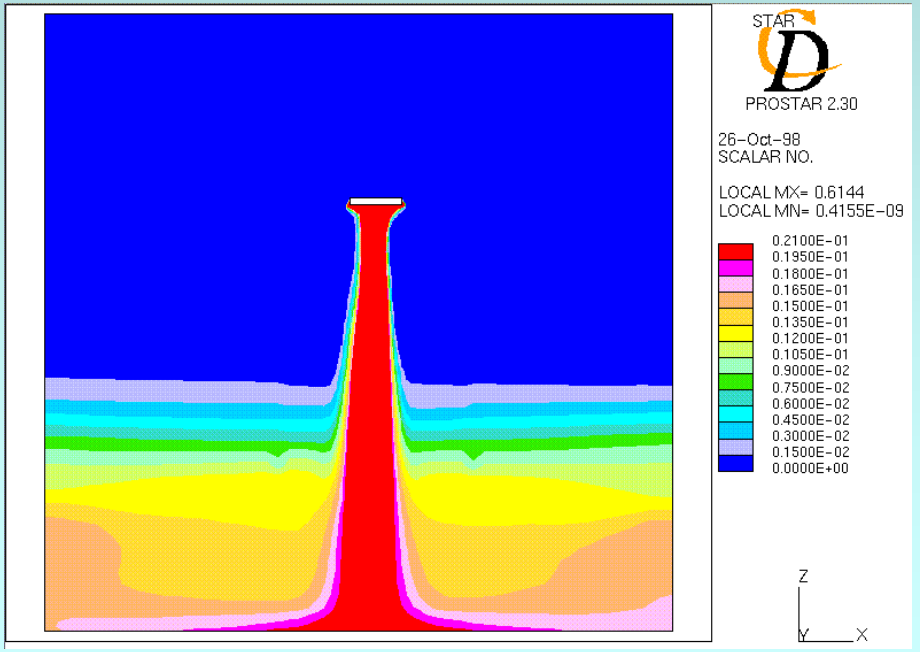
3.7 Pooling Effect

- IEC/ISO Joint working group developed the formula

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

  assuming stagnation with minimum velocity.
- Fast flow results in more homogeneous unlikely to make significant flammable cloud, if the charge follows the formula.





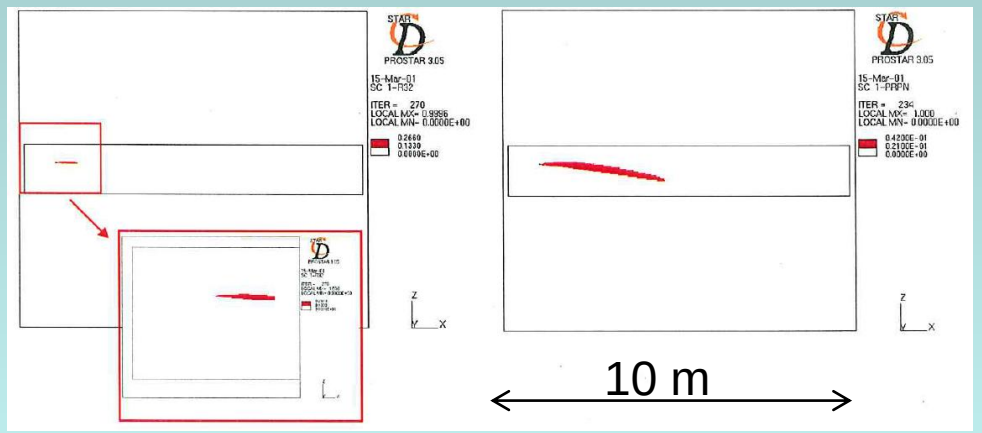
Details are published in ASHRAE SE-99-19-2 Experimental and Numerical Analyses of Refrigerant Leaks in a Closed Room

3.8 Difference in risk with rapid release

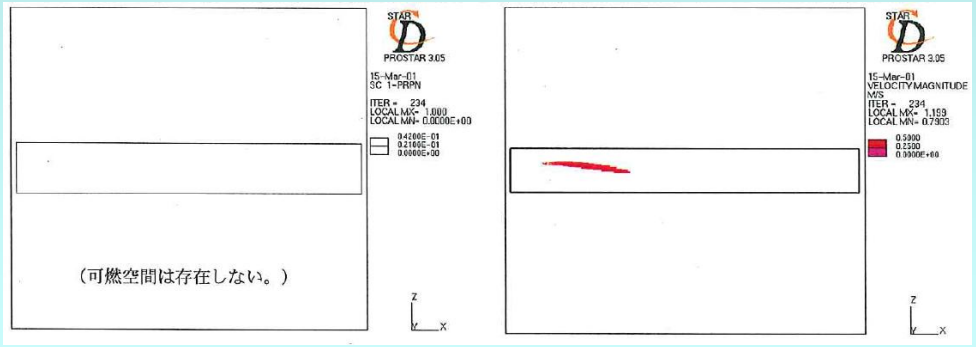
- CFD results indicate:
  - If flow velocity is considered, A2L does not generate flammable cloud.
  - Flow speed is too high to ignite where concentration is high enough.
  - Where velocity is low enough, concentration is too low.
- Accidental rapid release in service or else is almost impossible to ignite with A2L.
- Stagnation (pooling) is the issue.

R32 Propane

LFL



LFL
+speed

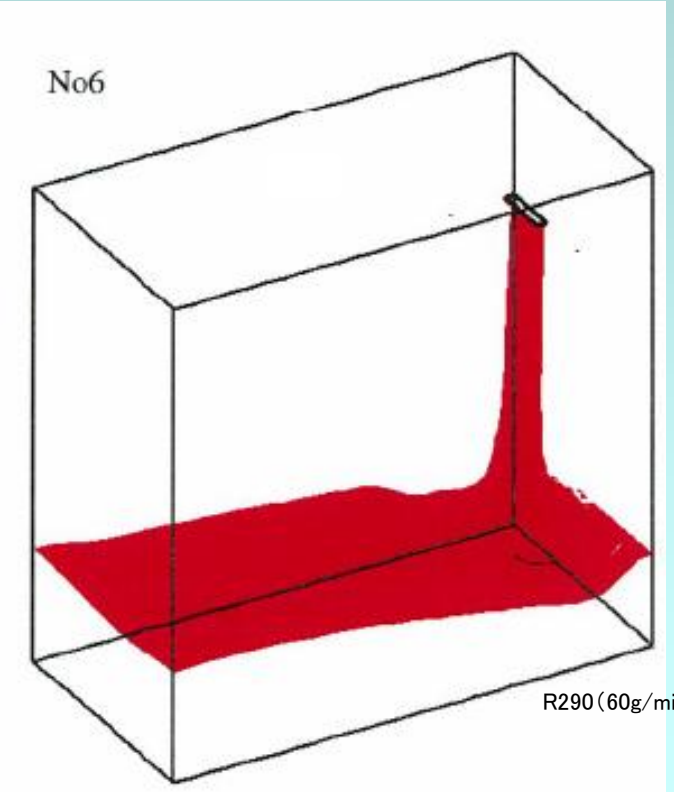


200 g /min release

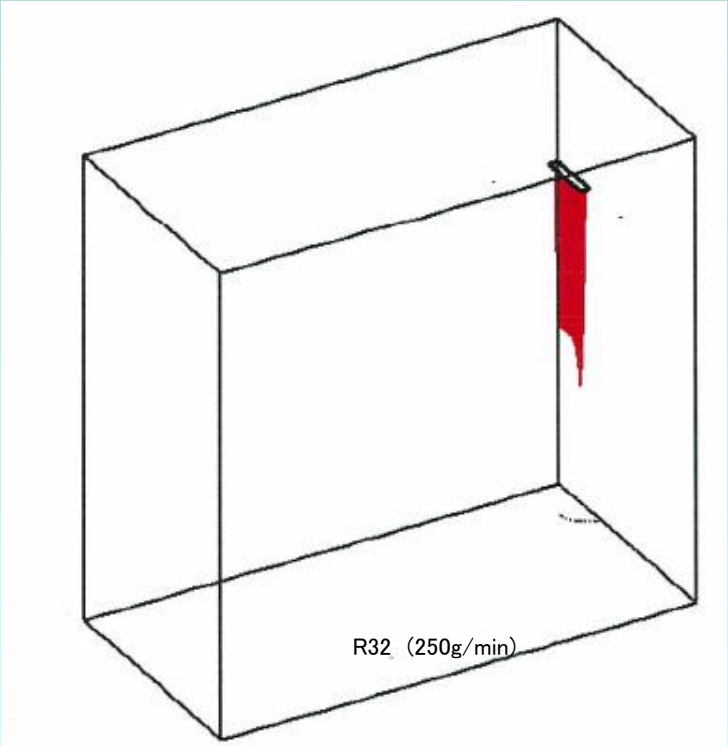
The data are calculated by Daikin

3.9 Difference between 2L and 3

- A2L class refrigerants dilute below LFL quickly due to heavy molecule and high LFL.
- Opening doors and windows are effective for 2Ls to avoid ignition, in case of accidental release during service.



Propane (60 g/min)



R32 (250 g/min)

CFD results (Red: LFL)

3.10 Decomposition Products

- Decomposition with combustion equipment or electric heater can happen with all CFCs, HCFCs, and HFCs regardless of flammability (Tokyo university of science measurement results.)
- It can reach fatal concentration, but it smells.

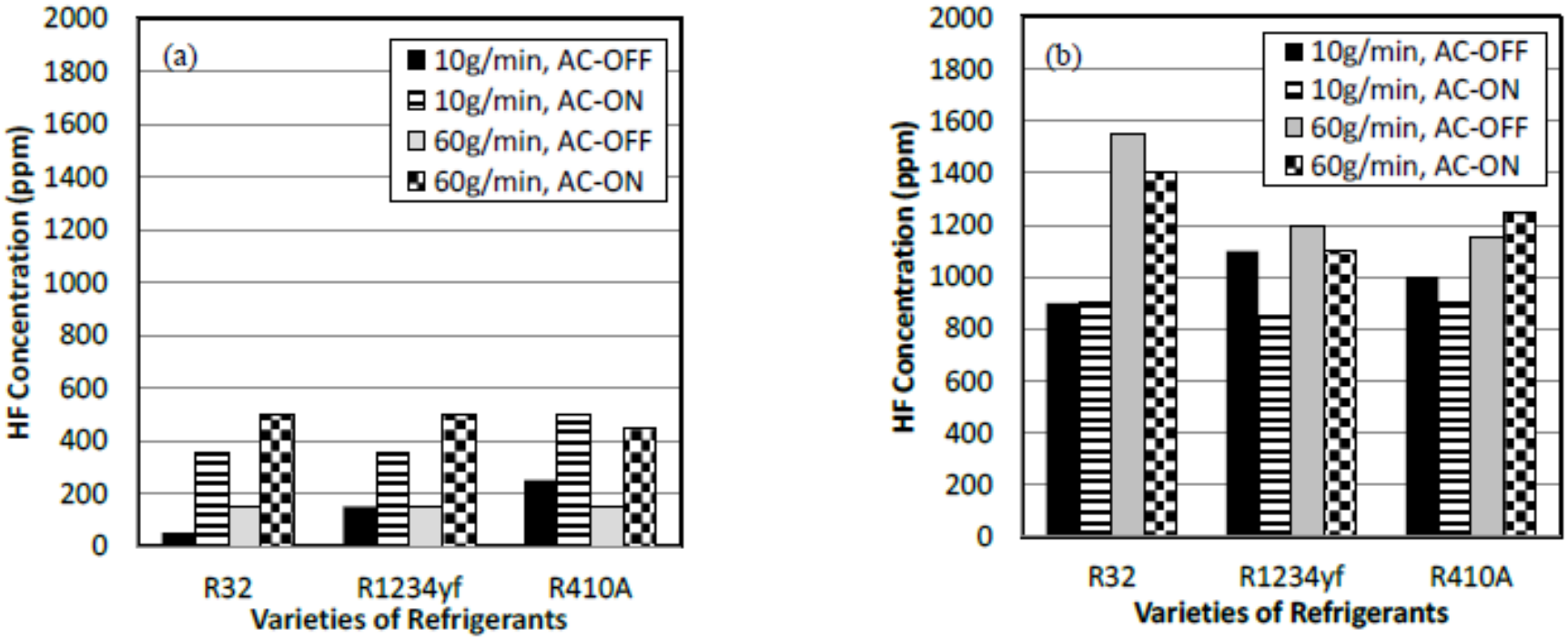


Fig.3.3.3 Comparison of HF concentration with leakage rate and operation of air conditioning system.
(a) using a radiation stove (b) using a fan heater

The data are quoted form the progress report of the project.

4. Overall Relative Risk

	Concentration limit	Other factor
HC Flammability Limit	40 g/m^3	Ignition source of HC is still less than population, but considerably exists.
R22 Toxicity Limit	210 g/m^3	Ignition source density of A2L is far less than population
A2L Flammability Limit	300 g/m^3<	

- Flammability limit of A2L is higher than toxicity limit of R22.
- Human density is much higher than the density of A2L ignition sources in most spaces.
- Approximated flammability risk of A2L is smaller than toxicity risk of R22.
- So, extreme care shall be taken with A2Ls for locations where experienced toxicity accidents with R22. (e.g. underground machinery rooms, piping pits, refrigerated food factory)

5. Other issues than flammability

- HFC has higher polarity in molecule than HCFC. Moisture is absorbed to most lubricant and damages the system (POE oil decomposition and other reaction).
- Large organic molecules are hard to solve to HFC refrigerants. Higher cleanliness of the refrigeration system is necessary to avoid sludge clogs at expansion device or else where.
- Pressure of R32 is slightly higher than R410A and about 1.6 times higher than R22.
- R32 has smaller molecular size than R22. Dryer (Molecular sieve) has to be suitable material.

Many service procedures, tools and components are different from ones for HCFCs and CFCs in addition to flammability.

Care has to be taken for such differences.

6. Conclusion

- A2L refrigerants are commercialized in some parts of the world and will be in other parts.
- Relatively higher risk in services for A2Ls.
- Flammability risk with A2L does not appear so high, as they are;
  - Hard to ignite due to high MIE and low BV
  - Unlikely to make flammable cloud due to high LFL in mass and volume.
- However, care for flammability has to be taken.
- In addition, care for HFC is necessary.
- Appropriate training for 2L refrigerants is necessary.

END

Thank you for your attention!