1.6

Experimental Evaluation of Physical Hazard of A2L Refrigerant Assuming Actual Handling Situations

The 24th IIR International Congress of Refrigeration (ICR2015)

Workshop: Research Project on Risk Assessment of Mildly Flammable Refrigerants

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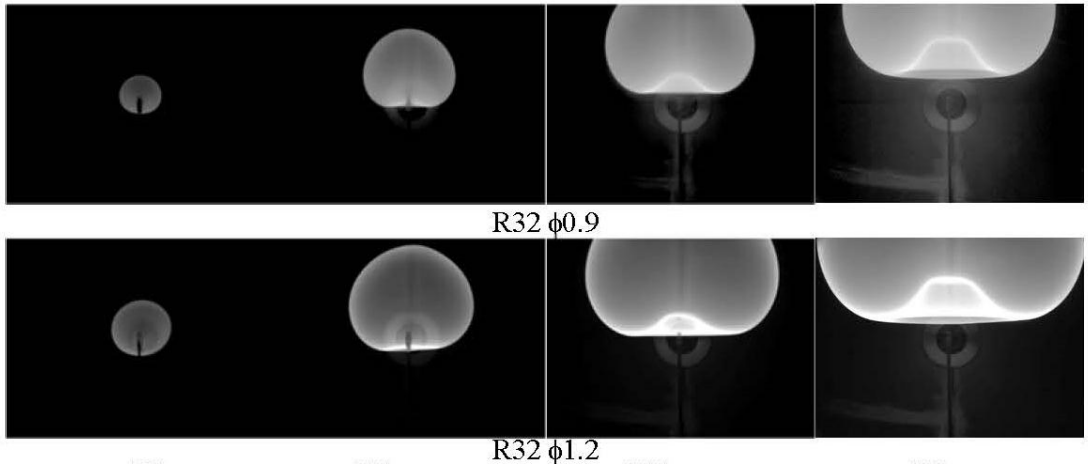
1. INTRODUCTION

Background & Objective (1/3)

Deregulation and utilization for A2L refrigerants

Probability of ignition and flame propagation	**Physical Hazard**	Damage by the combustion

Fundamental properties of combustion



Useful fundamental properties of combustion

have been obtained from

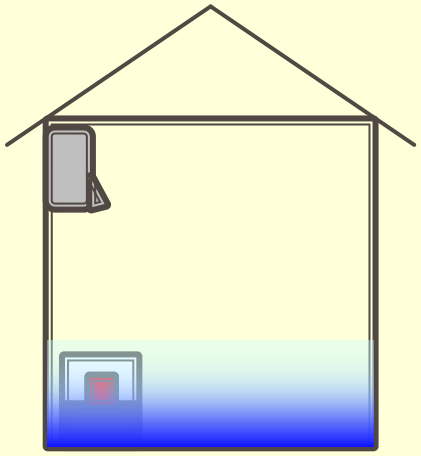
In the ideal environment
(no concentration distribution)
(no turbulence)

Ref.: Saburi, T. et al., Risk Assessment of Mildly Flammable Refrigerants, 2014 Progress Report, p.69, 2015, http://www.jsrae.or.jp/committee/binensei/2014PR_e.pdf

Background & Objective (2/3)

In the actual handling situation of air conditioning systems…

➢Leaked refrigerant generally has a certain degree of concentration distribution.



➢Ignition source is very various, and ignition behavior greatly affected by the turbulence and flow of the accumulated refrigerant.

We examined physical hazard by burning of A2L refrigerant **under several conceivable accident situations** based on these fundamental combustion behaviors.

Background & Objective (3/3)

Deregulation for A2L refrigerants

Risk assessment for A2L refrigerants based on the conceivable accident scenario is required.

Case1
Physical hazard evaluation in the case where an air conditioner containing an A2L-class refrigerant is simultaneously used **with a fossil-fuel heating system in a general living space**

Case2
Physical hazard evaluation **in the service and maintenance**

- In the case of using a lighter in the refrigerant-leaked ambient: evaluation of ignition possibility
- In the case that refrigerant leaks from a pinhole formed on the pipes or hoses
- In the case that refrigerant leaks into an equipment used to service and maintenance like a collection device

Case3
Physical hazard evaluation using **VRF** system

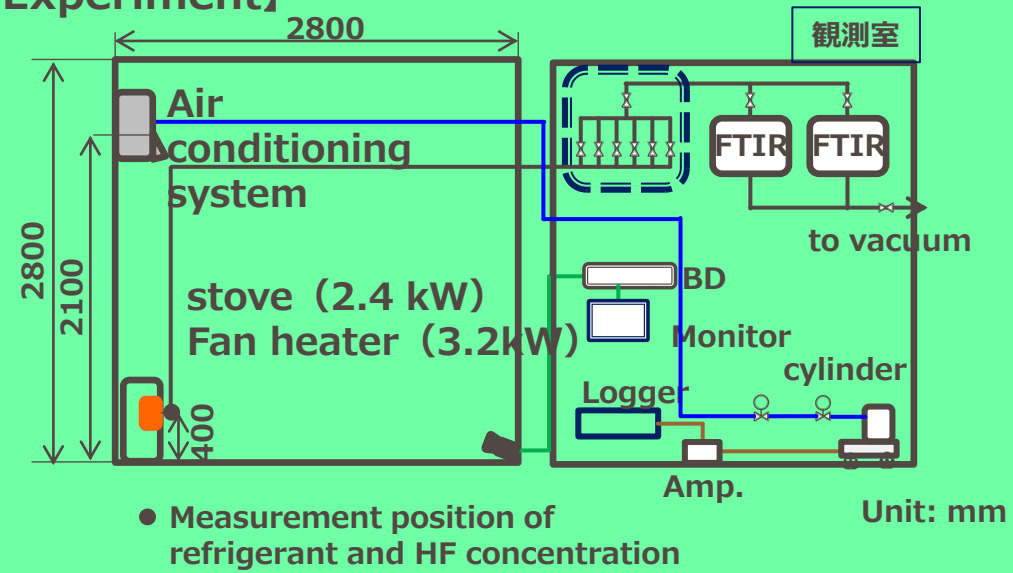
2. PHYSICAL HAZARD EVALUATIONS OF A2L REFRIGERANTS

2-1: Use with Fossil Fuel Heating System

Objective & Experiments

Accident scenario: A wall-mount type room air conditioning system containing an A2L refrigerant is simultaneously used with a fossil-fuel heating system inside a general living space.

【Experiment】



Refrigerants : R32, R1234yf, R410A

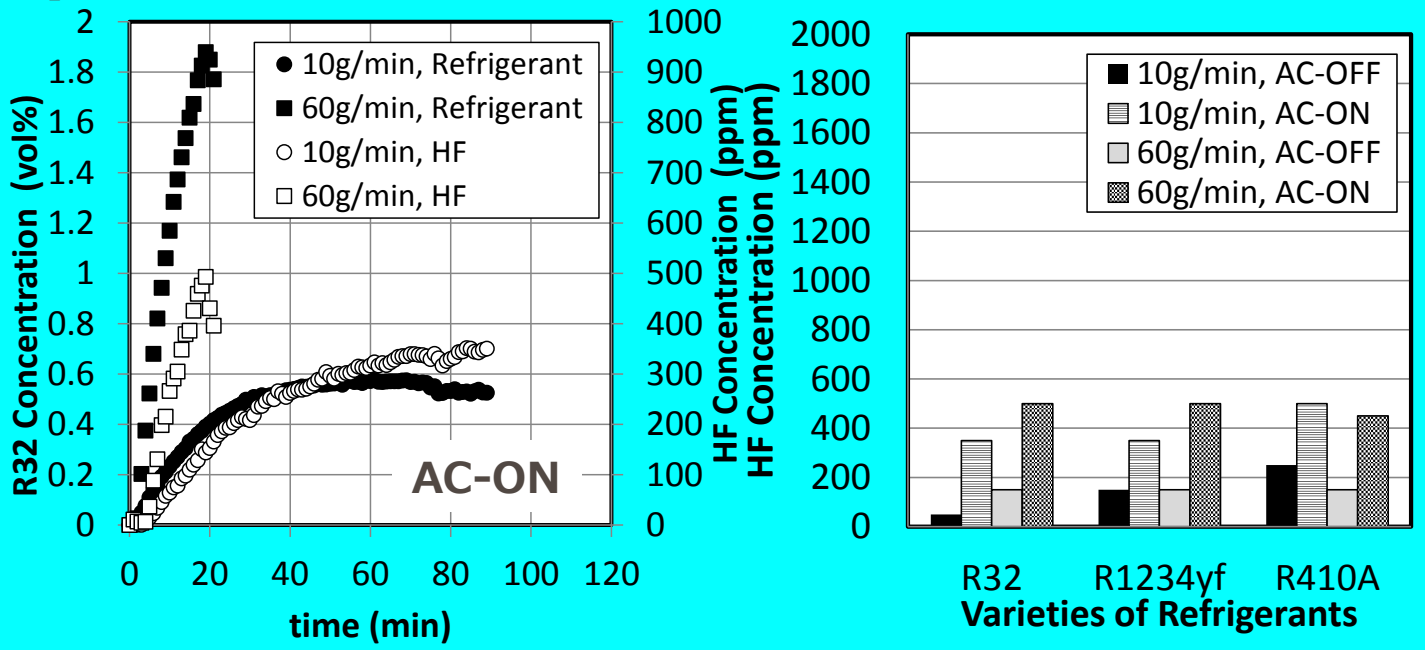
Leak amount : 800 g（generally installed in a commercial RAC）

Leak rate : 10 g/min, 60 g/min

Heater : radiative stove（2.4 kW）, oil fan heater（3.2 kW）

Experimental Results

【Results】 Heater: radiative stove



➢ **Refrigerant concentration (<2 vol%) was much lower than LFL. Therefore no ignition and flame propagation to A2L refrigerants were observed.**

➢ **Hydrogen fluoride which is generated due to the combustion or thermal decomposition was confirmed. The concentration of generated HF is more than 3 ppm which is the permissible value, even R410A.**

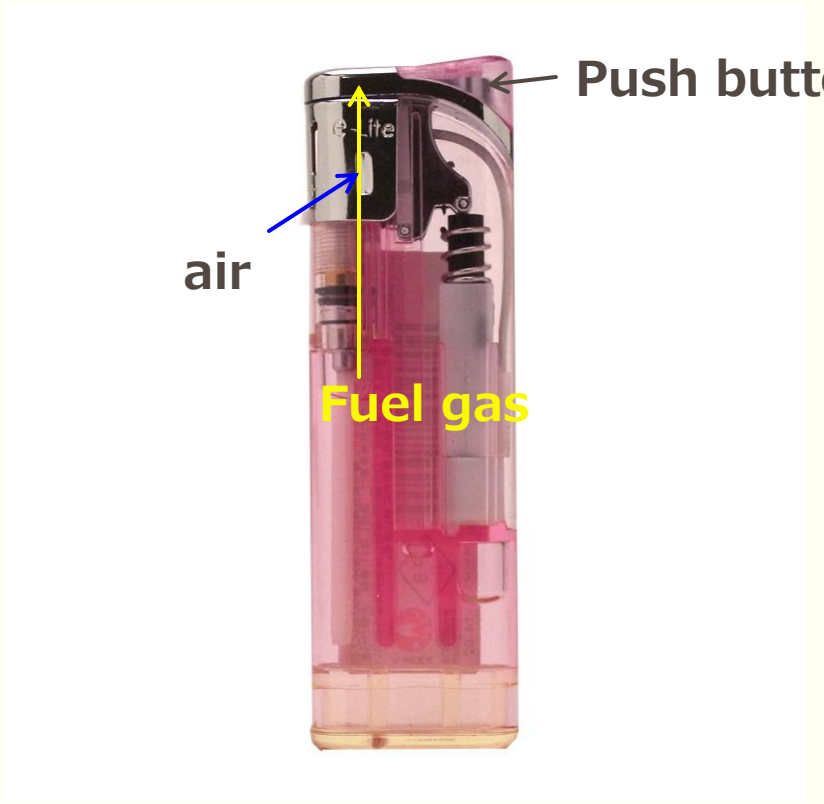
2. PHYSICAL HAZARD EVALUATIONS OF A2L REFRIGERANTS

2-2: Ignition and Flame Propagation Possibility by a Lighter

Objective & Experiments

Accident Scenario: A service operative uses a portable lighter to smoke in a space in which an A2L refrigerant has leaked and accumulated.

Type 1: piezo gas lighter



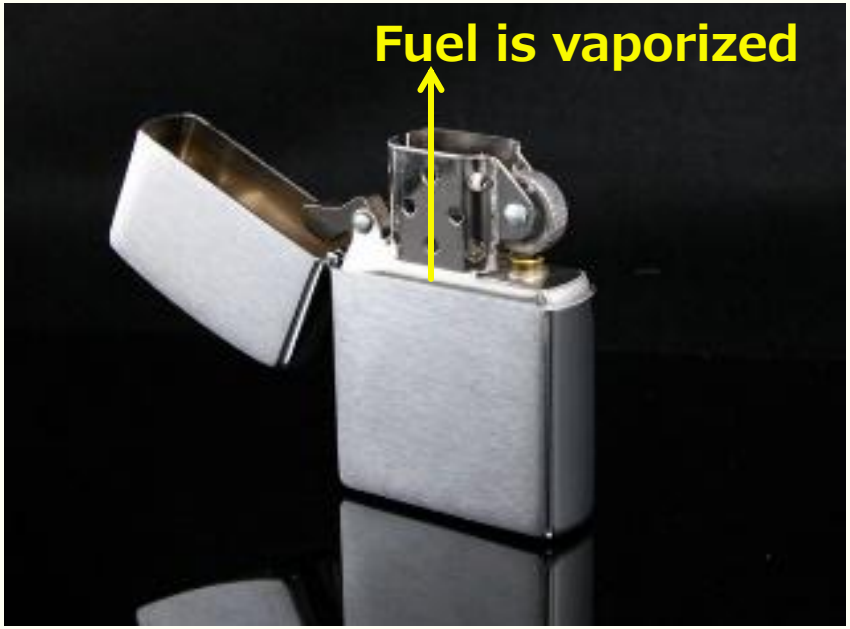
【Characteristic】

- Fuel gas is discharged **while a push button is pushed**.
- Mixture in the windbreak consists of fuel gas, air, and A2L refrigerant while a push button is pushed.
- Concentration of fuel gas is reached at least LFL at the outlet of fuel gas in the windbreak.
- The energy of piezo spark is approximately 1~5 mJ.

Objective & Experiments

Accident Scenario: A service operative uses a portable lighter to smoke in a space in which an A2L refrigerant has leaked and accumulated.

Type 2: Kerosene lighter



【Characteristic】

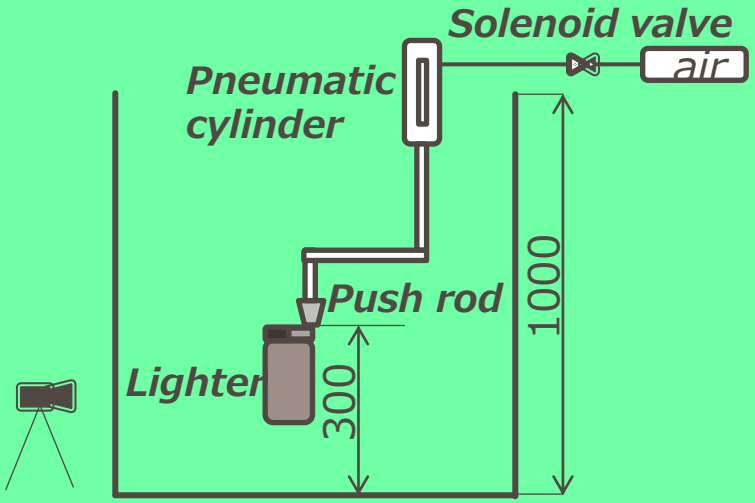
- Fuel gas is discharged **while a cap of lighter is opened**.
- Up-current of vaporized fuel is appeared **while a cap of lighter is opened**.
- The energy of spark generated by rubbing a flint is much larger than that of piezo element.

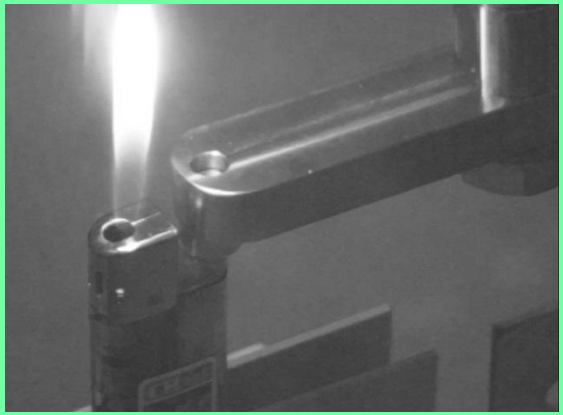
Objective & Experiments

Accident Scenario: A service operative uses a portable lighter to smoke in a space in which an A2L refrigerant has leaked and accumulated.

Type 1: piezo gas lighter

【Experiment】 Refrigerant: R1234yf, R1234ze(E), R32

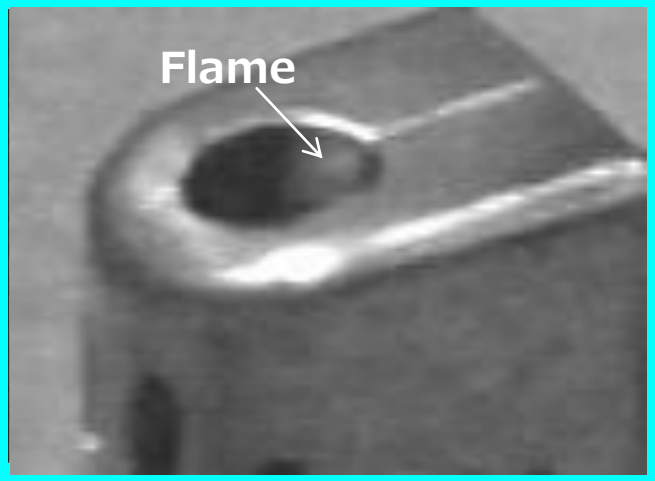




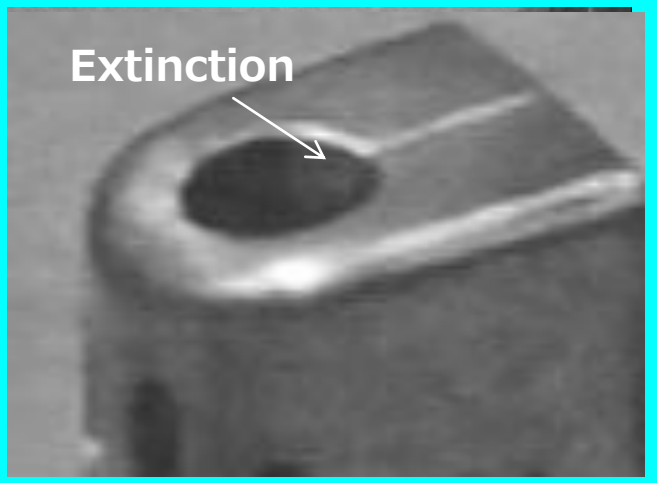
It was predicted that the concentration of n-butane/A2L refrigerants/air mixture is within the flammable range when the concentration of A2L refrigerants close to a gas lighter is less than LFL.

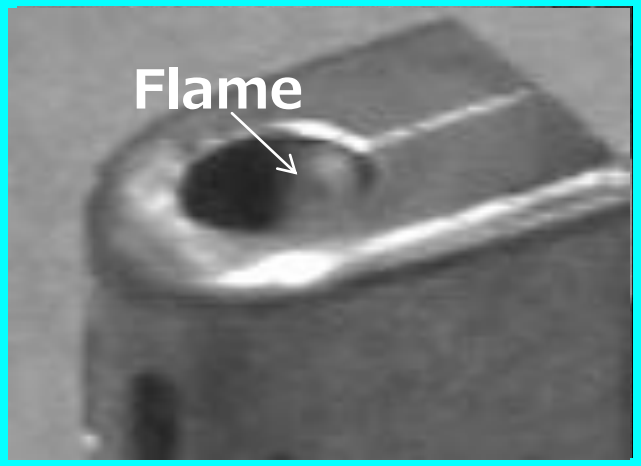
Experimental Results

【piezo gas lighter】



One frame passed (1/30 sec)





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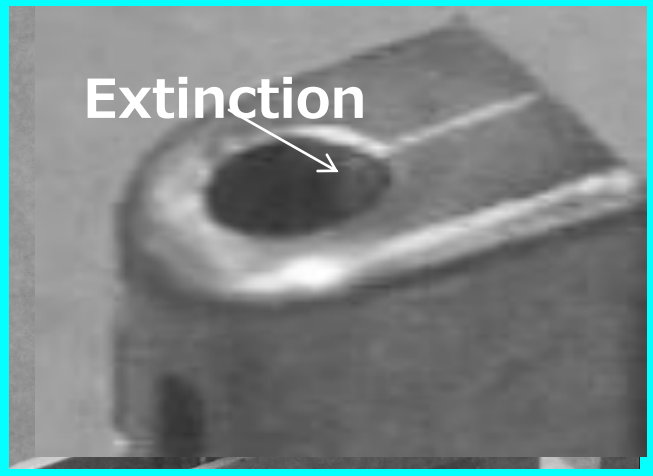


No ignition and flame propagation to accumulated A2L refrigerant was confirmed.

Objective & Experiments

Accident Scenario: A service operative uses a portable lighter to smoke in a space in which an A2L refrigerant has leaked and accumulated.

Type 2: kerosene lighter

【Experiment】

Enegization time : **50, 100, 500 ms**

AC spark at 100 ms of energization time

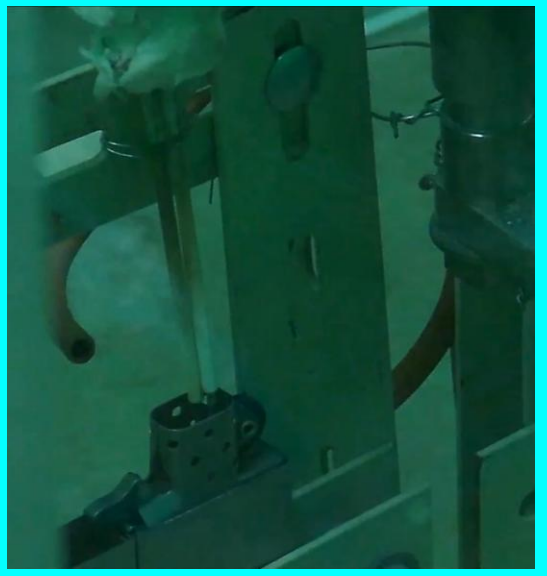
Experimental Results

【Kerosene cigarette lighter】

Ignition of a kerosene cigarette lighter was initiated by ac spark instead of the spark generated by rubbing a flint against a flint wheel directly.

Energization time : 50 ms

Energization time : 100 ms



Energization time : 500 ms

Refrigerant : R32, Refrigerant concentration at the lighter height : 16 vol%

Actual spark energy generated by rubbing : 1.2 J

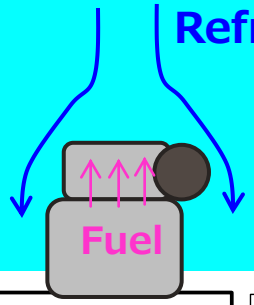
(Assuming that the composition of the flint alloy is 70wt% of cerium and 30wt% of Iron, and the mass of worn-down flint particle per one turn of flint wheel was 1.2×10^{-4} g)

Experimental Results

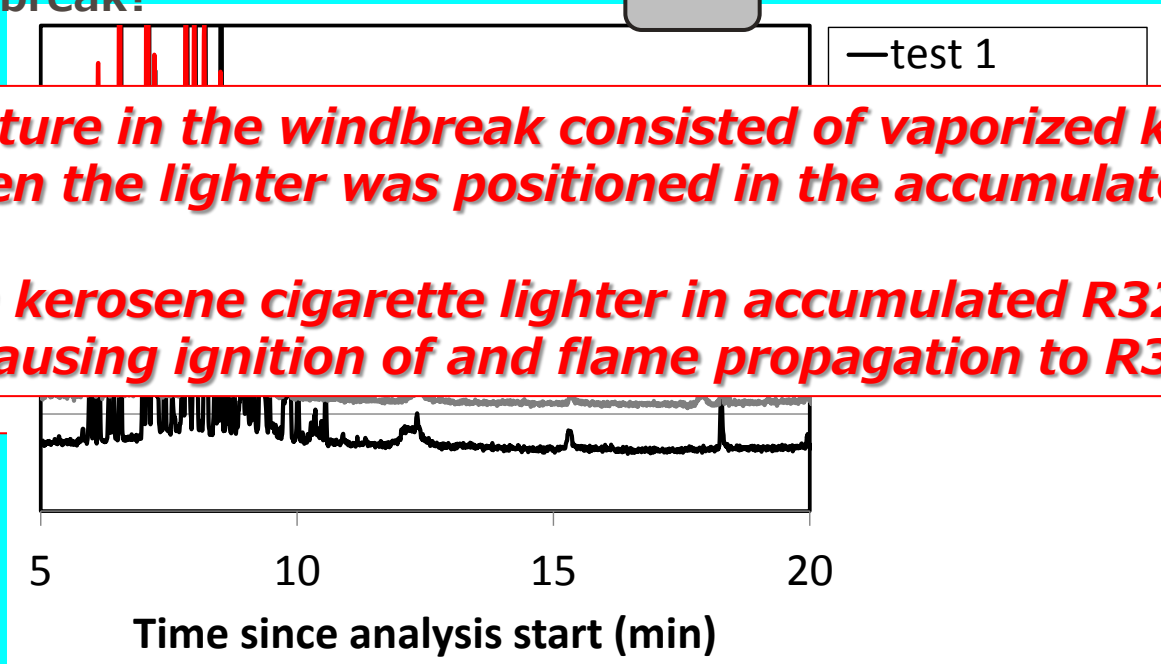
【Kerosene cigarette lighter】

Leak rate of refrigerant is small

Refrigerant cannot penetrate to the windbreak?



The gas in the windbreak was sampled and GC-MS analysis was carried out.



The gas mixture in the windbreak consisted of vaporized kerosene and air even when the lighter was positioned in the accumulated R32.

The use of a kerosene cigarette lighter in accumulated R32 might be capable of causing ignition of and flame propagation to R32.

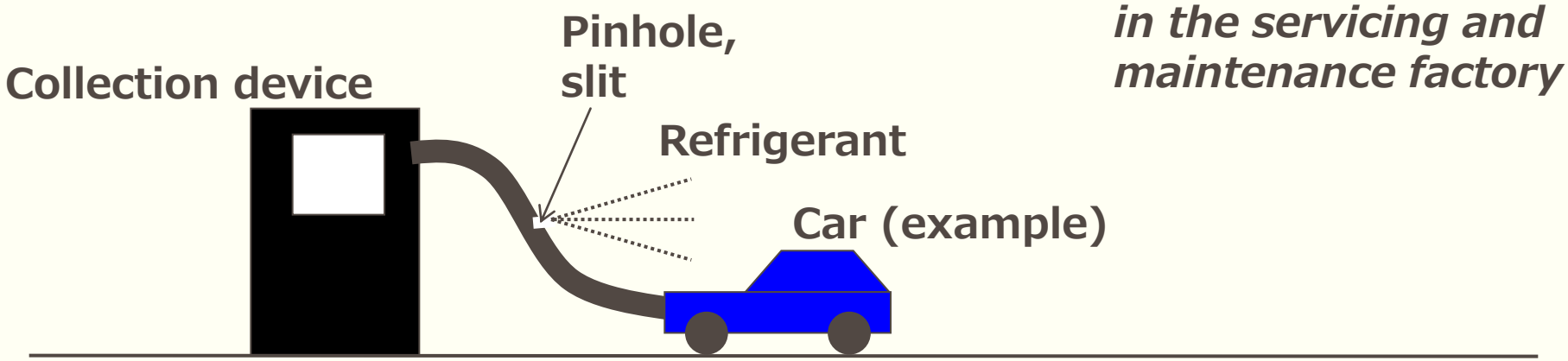
Si
fuel

2. PHYSICAL HAZARD EVALUATIONS OF A2L REFRIGERANTS

2-3: Physical hazard of rapid leakage from a pinhole

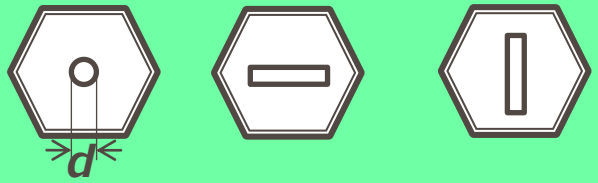
Objective & Experiment

Accident Scenario: An A2L refrigerant leaks from a fracture or pinhole in the pipes or hoses such as that used to connect a car's air conditioning system to a collection device.



Refrigerants : R32, R1234yf, R1234ze(E)

Pinhole :



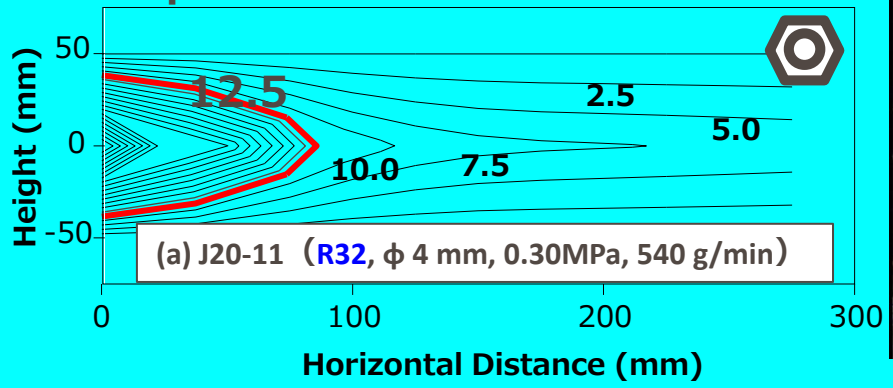
***d*=0.2, 1.0, 3.0, 4.0 mm**
Slit: 1.0 x 4.0 mm

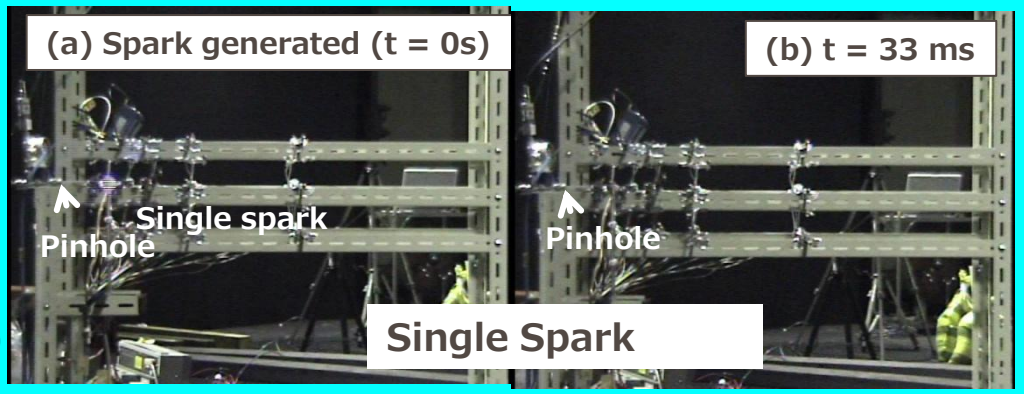
Mass flow rate : 5.0-847 g/min

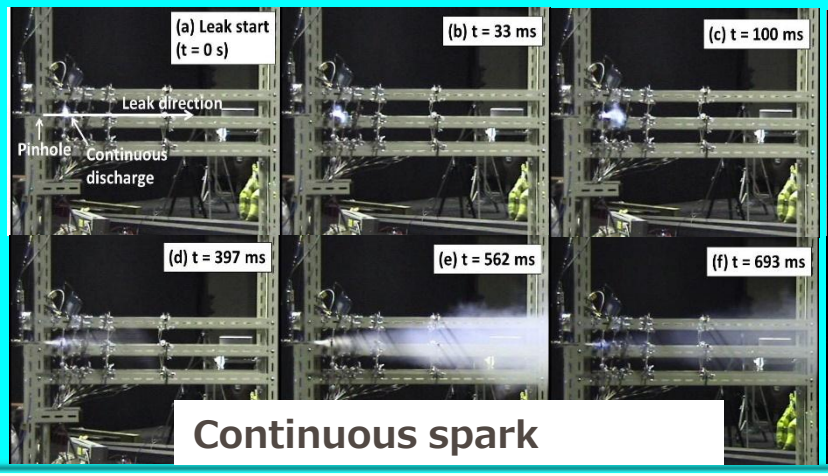
Ignition source : single spark, continuous spark, open flame

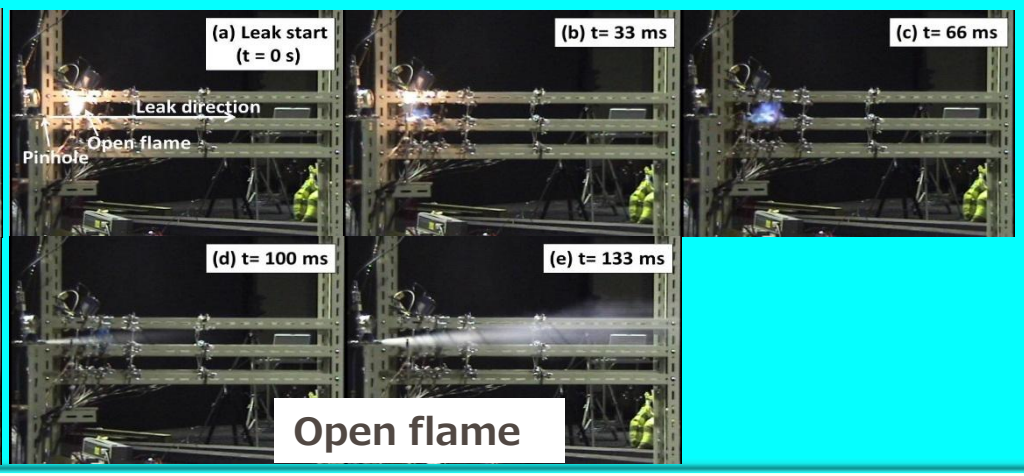
Experimental Results

【Experimental Results】









The flammable zone was formed only in partial areas.

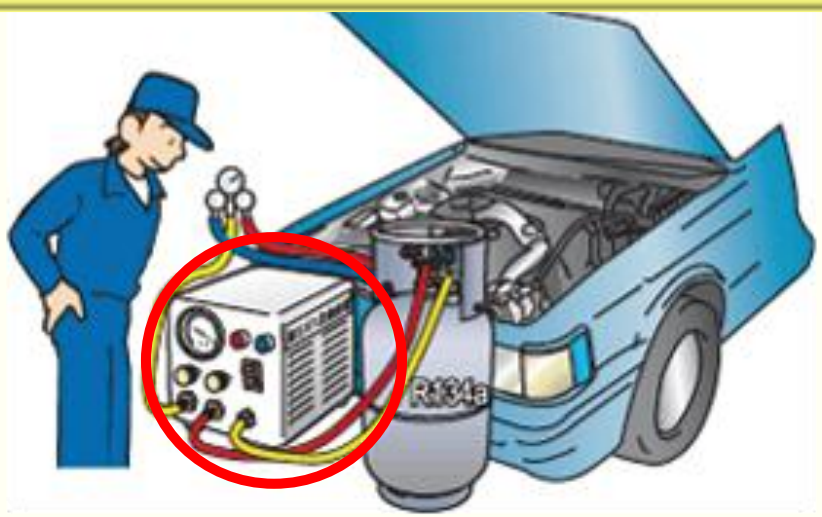
No ignition and flame propagation to the entire A2L refrigerant was observed.

2. PHYSICAL HAZARD EVALUATIONS OF A2L REFRIGERANTS

2-4: Physical Hazard of Leakage into the Collection Device

Objective & Experiment

Accident Scenario: An A2L refrigerant leaked to inside of an equipment used for service and maintenance such as a collection device.



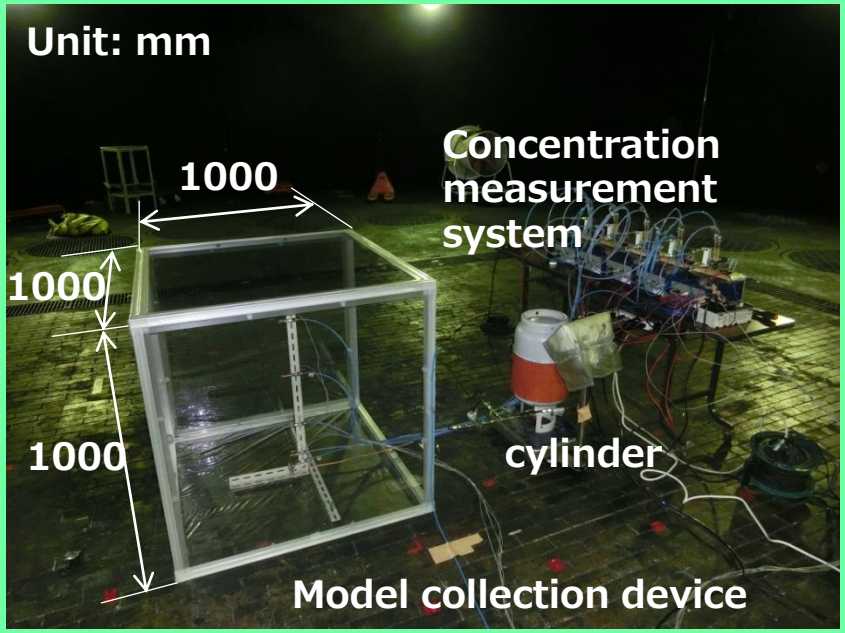
http://www.jraia.or.jp/htdocs_test2/product/flon/index.html

We examined…

- ➢leakage and ignition behaviors of A2L refrigerant in a model collection device.
- ➢especially the effect of slit fixed in the collection device to prevent the accumulation and ignition of leaked refrigerant.

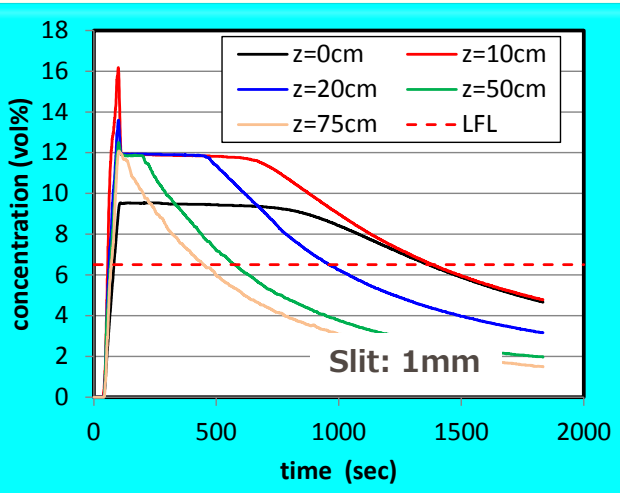
Experiment

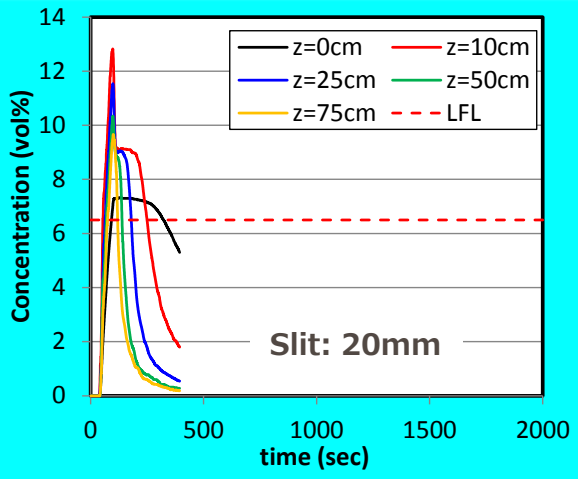
【Experiment】

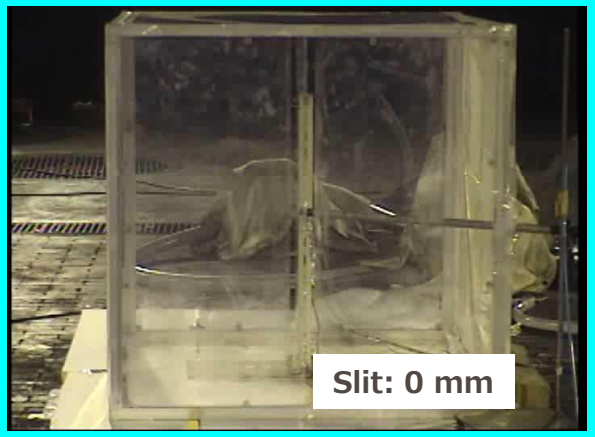


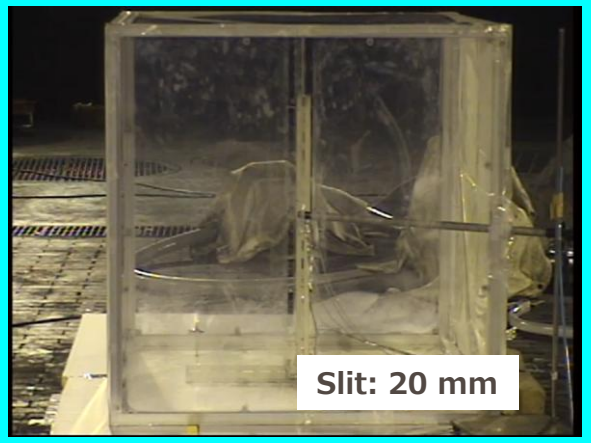
Location of measurement of concentration :
0, 10, 25, 50, 75 cm above the bottom of model collection device
Ignition source : DC spark discharge（energy: 16J, 6Hz）
Slit width : 0 (close), 1, 5, 10, 20 mm
Varieties of refrigerant : R1234yf

Experimental results









The ignition possibility could be reduced by fixing slit having suitable width.

3. CONCLUSIONS

Conclusions

We conducted the physical hazard evaluation on A2L refrigerant assuming conceivable accident scenarios experimentally.

➢Use with Fossil Fuel Heating System

➢Refrigerant concentration (<2 vol%) was much lower than LFL. Therefore no ignition and flame propagation to A2L refrigerants were observed.

➢ Hydrogen fluoride which is generated due to the combustion or thermal decomposition was confirmed. The concentration of generated HF is more than 3 ppm which is the permissible value, even R410A.

➢Ignition and Flame Propagation Possibility by a Lighter

➢When a piezo gas lighter was used in the accumulated R32 and R1234yf, no ignition and flame propagation was observed.

➢But when a kerosene cigarette lighter was used under the slow leak condition, ignition and flame propagation was observed.

Conclusions

➢Physical hazard of rapid leakage from a pinhole

➢The flammable zone was formed only in partial areas.

➢No ignition and flame propagation to the entire A2L refrigerant was observed.

➢Physical Hazard of Leakage into the Collection Device

➢The ignition possibility could be reduced by fixing slit having suitable width.

ACKNOWLEDGEMENTS

Acknowledgements

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Lake Suwa, Japan, 2013.