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Nature Protects if She is Protected

LiFE
Lifestyle for Environment

PROKLIMA
NATURALLY COOL

Demystifying R290: Lessons Learned from the Development of High-Efficiency Compressors and Microchannel Heat Exchangers for Room Air Conditioners



Organised by GIZ Proklima in collaboration with National Ozone Unit (NOU), India

At MOP 38**; Date:** 3rd November 2026**; Venue:** Kigali, Rwanda

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Agenda Item	Speaker
Opening Remarks	***Simon Triebel*** Federal Ministry for Economic Cooperation and Development, Government of Germany
Keynote Address	***Mr Aditya Narayan Singh*** Scientist F, Ozone cell, Ministry of Environment Forests and Climate Change (MoEFCC), Government, Government of India
Knowledge sharing on lessons learned and approach: R290 compressor development	***Mr Abhishek Sharma*** Plant Head – Mohali, India, Godrej and Boyce Pvt Ltd (virtually)
Presentation on R290 risk assessment study	***Dr Daniel Colbourne*** Re-Phridge Ltd, UK, and international expert consulting this project
Discussion and audience interaction	***All participants***
Closing remarks: Key messages on future priorities from Ozone cell and GIZ	***Mr Guntram Glasbrenner*** Programme manager, Proklima, GIZ

Welcome Remarks

Simon Triebel

Federal Ministry for Economic Cooperation and Development, Government of Germany

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Keynote Address

Mr Aditya Narayan Singh

Scientist F, Ozone cell, Ministry of Environment Forests and Climate Change (MoEFCC), Government, Government of India


Godrej

GODREJ GROUP

- *Established in 1897*
- *Over 129 years old company*
- *India's Largest privately held company*

Land area in Vikhroli - 3200 acres

1750 acres is reserved for conservation of Mangrove Forests



GODREJ ENTERPRISES GROUP































Public

Project title

Design and Development of a pilot-scale energy efficient rotary compressor along with micro channel heat exchange for R290 technology at Godrej & Boyce Mfg. Co. Ltd.

Public

Scope :

- Design Develop & Prototype a Rotary compressor for maximum EER matching benchmarked imported compressor.
- Test and iterate design and get it up for field trials.
- Design a MCHX suitable for the load of 5000Watts & iterate design to gain maximum ISEER in AC with R290.
- Finally integrate compressor / MCHX /Evaporator coil / EEV etc.in AC to get maximum ISEER using R290.

Status – Development of energy efficient R-290 compressor

- Design and development of all compressor parts. **Completed.**
- About 99 proto and testing of parts. **Completed**.
- Higher benchmarked EER of imported GMCC compressor 3.5 achieved. **Completed**.
- Compressor validation in internal lab and in third party external BIS approval lab. **BIS approved compressor**.
- Equipment ordered and received as per approved grant for pilot. **Completed.**
- Over 400 compressors made and put in field for assessing reliability and performance. **Completed**.

First basic requirement is completed by Dec 2025

Godrej

Status – Development of MCHX for R-290 use in Air conditioners

- MCHX design completed and drawings made. **Completed**.
- Samples fabricated with vendor to evaluate actual performance. Gap of 5 to 6 % was observed.
- MCHX design iterated and 2nd sample fabricated and confirmed suitability for getting higher ISEER in Air conditioners
- Small lot of MCHX ordered for purpose of integration into Air conditioners.

Second part of MCHX development completed

Status – Integration of compressor and MCHX into Air conditioners with related sizing of evaporator coils/EEVs and charge

- Evaporator/compressor/MCCHX/EEV for 1 ton and assembled and charge iterated to get maximum ISEER. **Achieved 5.8 ISEER**.
  (5 Star till Dec 2027 – 5.6 ISEER)
- Evaporator/compressor/MCCHX/EEV for 1.5 ton and assembled and charge iterated to get maximum ISEER. **Achieved 5.8 ISEER**.
  (5 Star till Dec 2027 – 5.6 ISEER)
- Machines sent to third party for energy and BIS testing.
  All BIS test cleared in third party labs
  ISEER for 1 ton – 6.0 in third party labs
  ISEER for 1.5 ton – 5.8 in third party labs.

Third part of integration completed

Godrej

Public

Challenges and their resolutions.

- Compressors need very high accuracy parts even for prototypes else results are misleading.
  - Use of our experience of reciprocating compressor manufacturing, internal machining and also some external machining helped get the accuracy but time got extened.
  - About 99 trials and prototypes made before success could be seen.
- MCHX was a must to get R290 quantity within limits of standards BIS & IEC.
  - Support taken from auto industry to help design and build the MCHX.
  - MCHX for AC has very different form factor hence getting prototypes made was time consuming as equipment's at auto industry has limitation of size. Hence work done on holidays etc.

Public

Challenges and their resolutions.

- Integration of all items in ACs to get maximum ISEER with adherence to standards and charge quantity limitations.
  - Our earlier experience of R290 usage in AC along with usage of MCHX new design helped. Keep charge within limits.
  - Our AC plants were TUV certified for R290 usage, hence charging and safety were taken care of.

Conclusions

- Compressor development and field testing started. BIS approved
- MCHX and other components integration achieved. To get -
- ISEER – 6 for 1 ton
- ISEER – 5.8 for 1.5 ton
- Models and results uploaded on BEE portal
- Model and results uploaded on BIS portal.
- All BEE and BIS reports by third party submitted to Ozone cell and GIZ.

Project Completed.

Public

Way forward :

- Work to continue compressor EER improvement.
- Work further to stabilize MCHX supply.
- Work to see if ISEER can be achieved without MCHX.
- Godrej will support and help any other industry for moving to R290 in terms of guidance, samples, evaluation.
- Godrej will support any other country’s program by supply of information, samples and training to people.
- We will follow the country program to phase down HFC by starting to introduce R290 AC again in the market using our compressors towards end of 2026.

Project Completed.

Public

Updates on Rotary compressor manufacturing Facilities

Compressor Manufacturing

Grinding Section



Machining section



Public

Metrology Section



ROTARY COMPRESSOR ASSEMBLY SECTION



Public

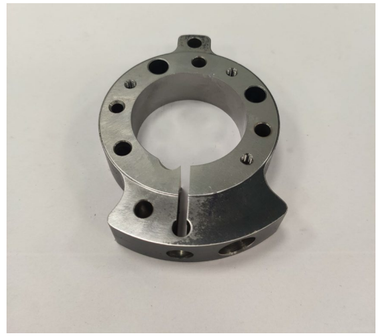
Various parts of Rotary Compressor



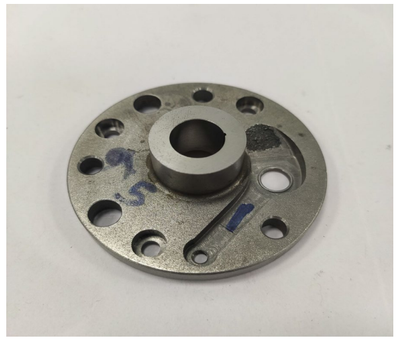
Rolling piston



Crank shaft



Lower chamber



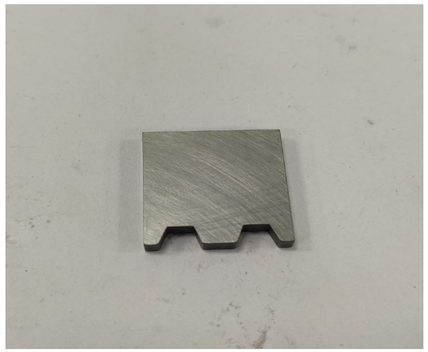
Lower Bearing



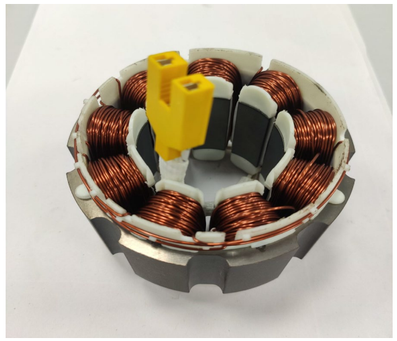
Upper chamber



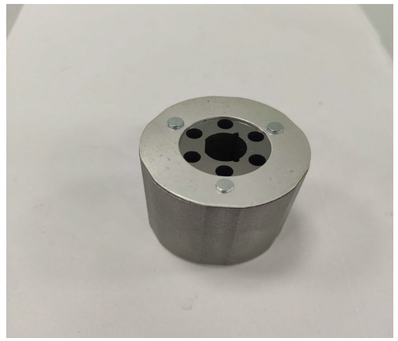
Middle plate



Vane



Stator



Rotor



Suction muffler



Lower bearing cap



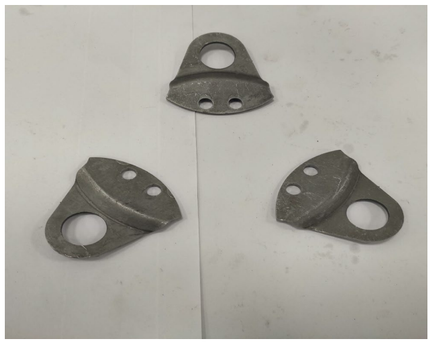
Upper bearing cap



Middle shell



End cups

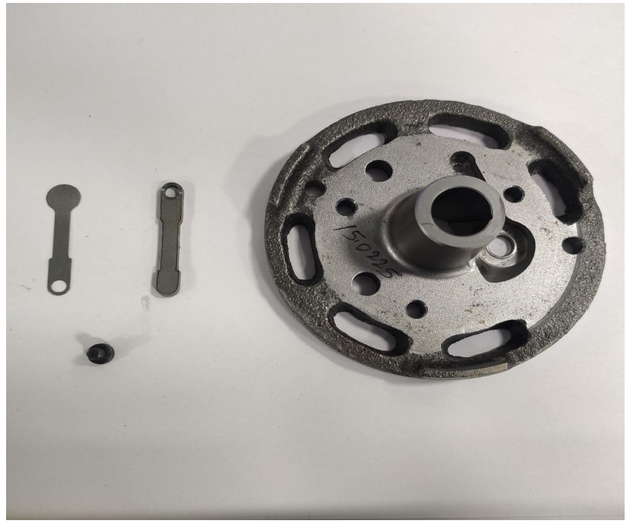


pedestal

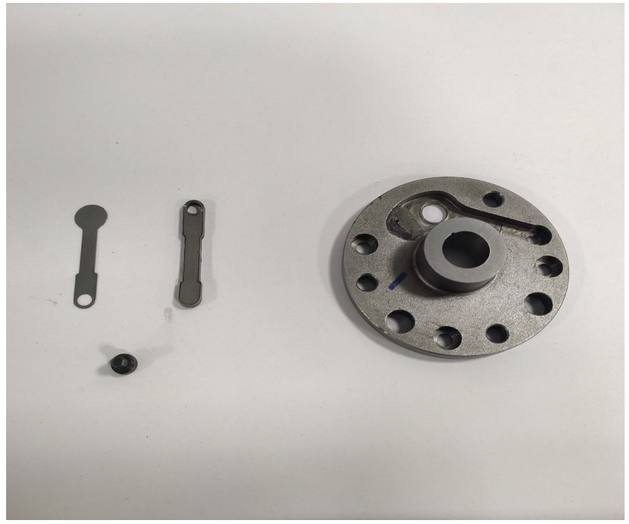
Public

Upper & Lower bearing sub assembly and Testing

Upper Bearing, Reed ,retainer



Lower Bearing, Reed ,retainer





Assembly Fixture

Leak testing of upper and lower Bearing sub assembly

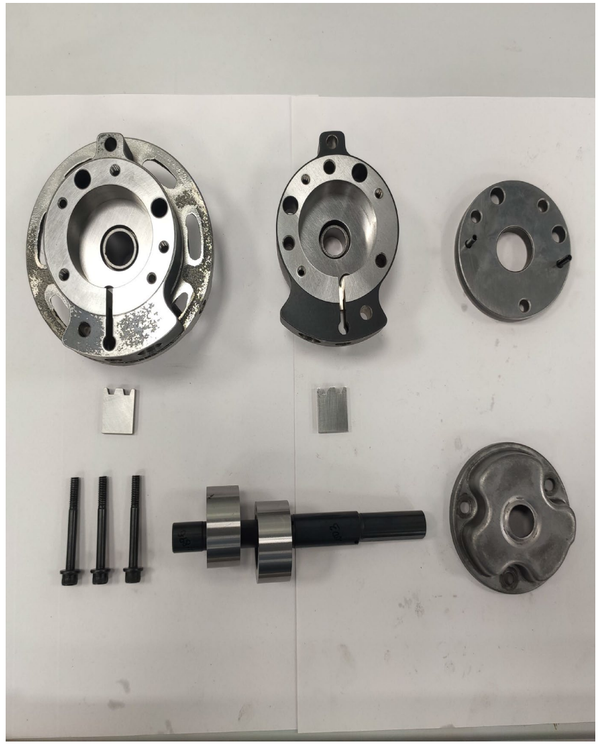


Leakage rate < 5 LPH is Ok

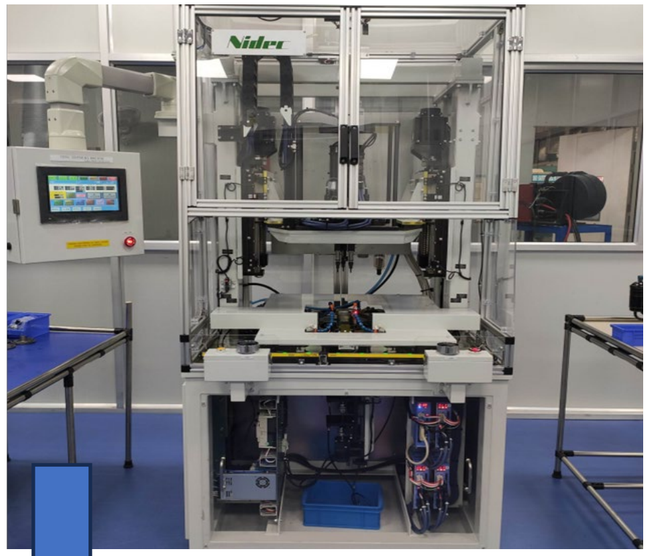
Pump assembly

Public

Bearing & Chamber sub assembly, Crank shaft, Vanes, Rolling piston



Bearing and chamber cantering machine



Total Cantering machine



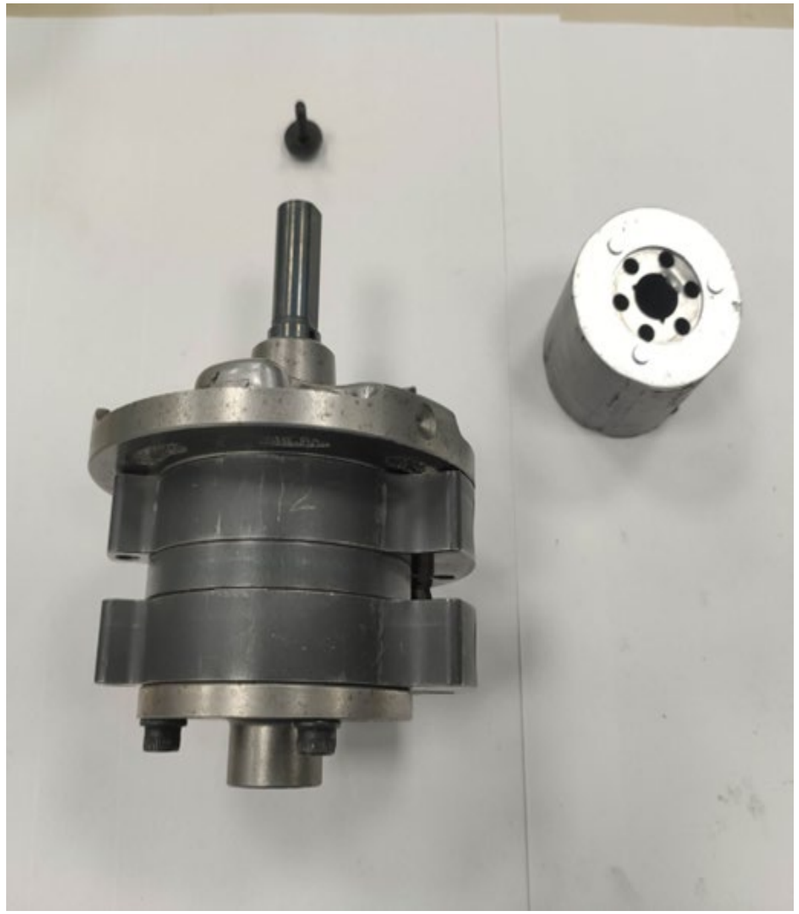
Pump assembly



Public

Pump and Rotor assembly

Pump ,Rotor and screw



Fixture for Pump ,Rotor and screw
Assembly to prevent rotation while torquing



Pump & Rotor assembly



Pump & Rotor assembly is ready for welding process

Public

Shell and Motor assembly-Shrink fit

Shell & Motor



6 station rotary indexer



Actual machine photograph



Shell and Motor assembly-Shrink fit: Shell is expanded by heating up to 250 degrees and motor is fitted after expansion. After cooling shell shrinks and holds the motor.

Public

Shell & end cap welding

Shell, Motor and pump assy. with end covers



Fixture with 2 torches for 360- degree end cap welding



END cap Welding machine



Both the end caps are welded with shell simultaneously by 2 welding torches and shell rotates 360-degree.

Public



Godrej manufactured rotary compressor

Public

AC Manufacturing Testing Facilities

Public

Vacuum Tank Leak Detector Machine



Public

ODU Performance Testing



IDU Noise Testing Lab



Psychrometric Lab



Public

Thank you

GIZ/Godrej R290 split AC lifetime quantitative risk assessment (QRA)

November 2026

GIZ-Godrej AC project

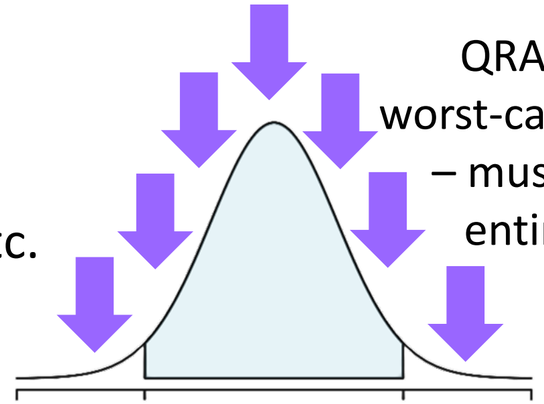
Daniel Colbourne

dc@re-phridge.co.uk

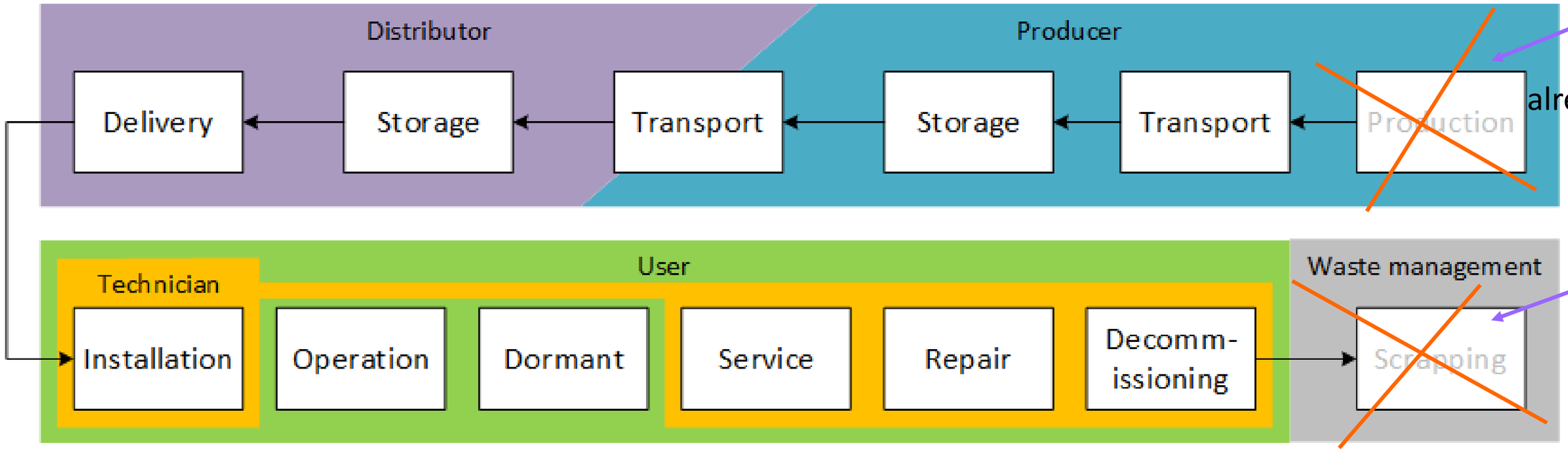
Split AC lifetime flammability risk assessment

Quantify risk parameters – ignition frequency, risk of overpressure, thermal dose for each:

- Stages – producer, distributor, user, technician
- Activities – moving, storing, delivery, installing, operating, dormant, repair, etc.
- Locations – warehouse, lorry, van, loading area, dwelling, balcony, etc.
- Operating modes – off, on
- Speeds – wind, driving, etc



QRA is NOT worst-case only – must cover entire span



Production (in factory) – RA assessment already completed

scrapping not addressed – involves negligible amounts of refrigerant

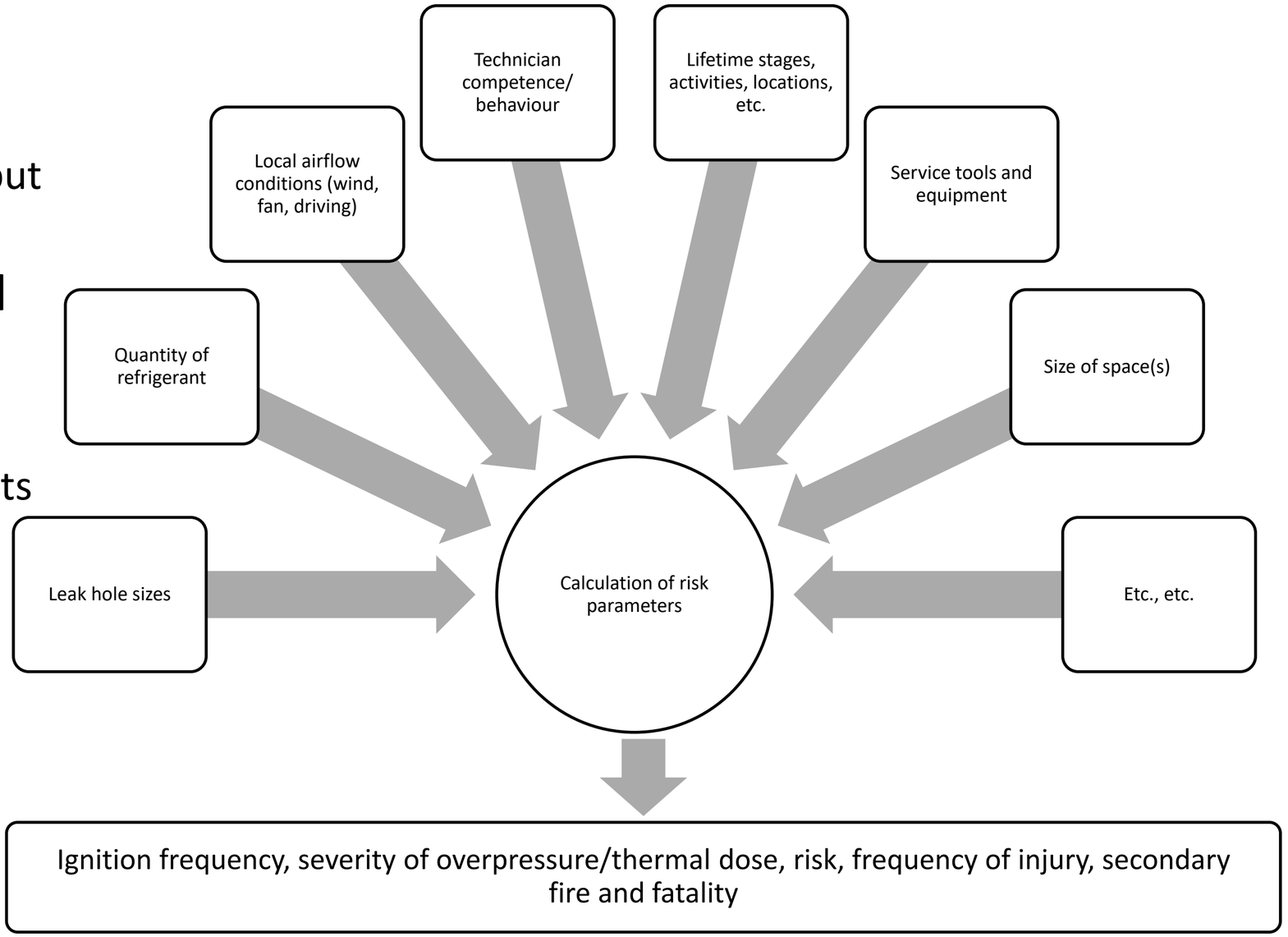
Overall risk model

Accounts for various input parameters, variables, etc.

- All affect, to some extent, the output risk values

Calculations draw upon physical measurements, observations, statistical data

- Leak simulation/ concentration tests
- CFD calculations
- Leak quantity tests
- Site activity observations
- Leak hole size measurements and repair databases
- Discussions with various stakeholders



Technician activities

Divided according to specific tasks necessary for completing an activity

- Different tasks combined to form a particular activity
- Each task involves potential releases and ignition sources

Installation

- Area and equipment checks
- Sealing system
- Pressure testing
- Evacuate and charge
- Close system
- Leak testing

Wet cleaning

- Area and equipment checks



- Wet/cleaning

Repairs

- Area and equipment checks
- Opening system
- Removing refrigerant
- Breaking into system
- Sealing system
- Pressure testing
- Evacuate and charge
- Close system
- Leak testing

Decommissioning

- Area and equipment checks
- Opening system
- Removing refrigerant
- Breaking into system

Outcomes affected by

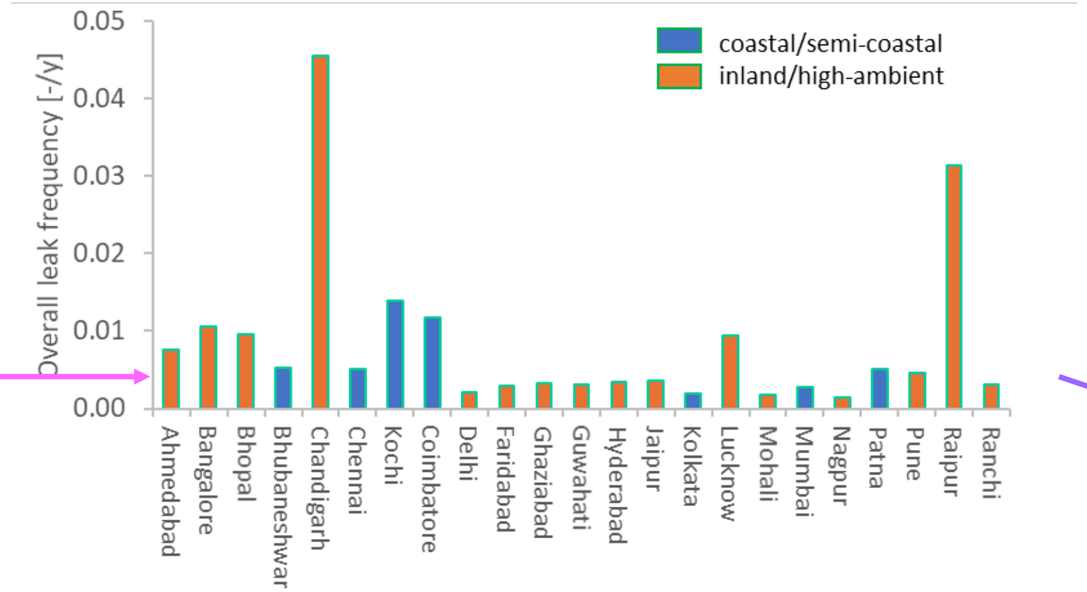
- Technician competence/ behaviour
- Available tools and equipment
- Local conditions

Leak frequency

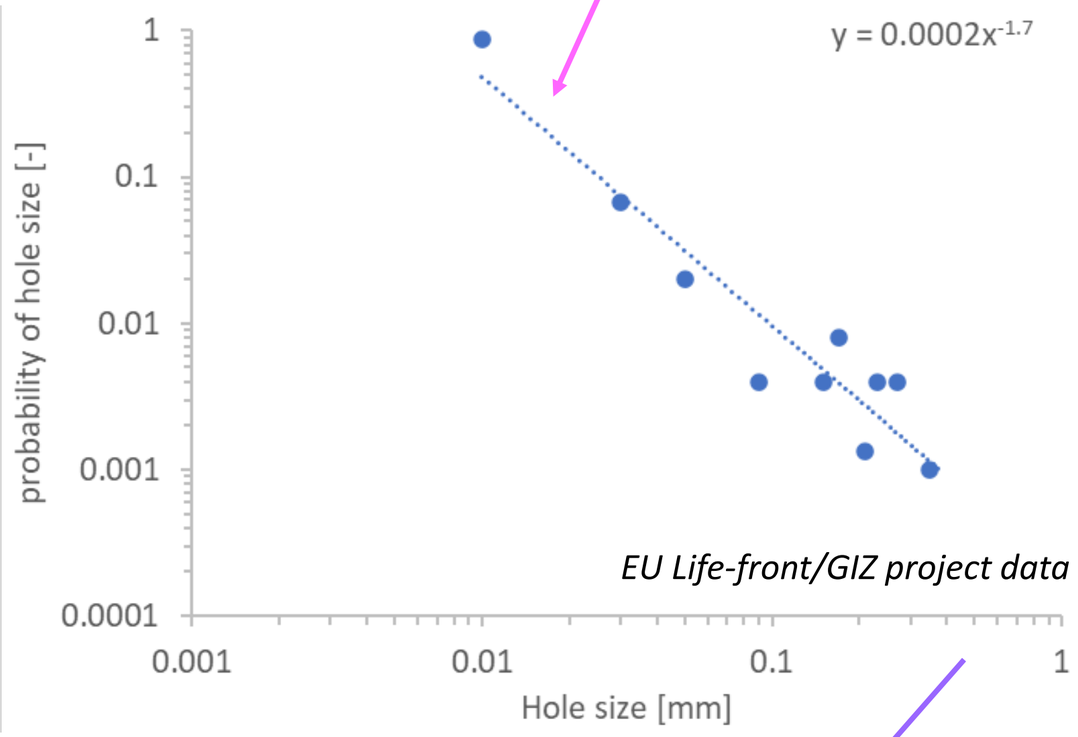
Crucial information for a QRA

- Leak frequency (based on Godrej data), overall 0.0048 y^{-1}
- No significant differences between coastal and inland
- Some anomalous peaks…
- Leak frequency correlation constant adjusted to fit Godrej data

Average over whole data-set



Leaks from indoor parts about 26% of total



All used to determine frequency of 10 different hole sizes

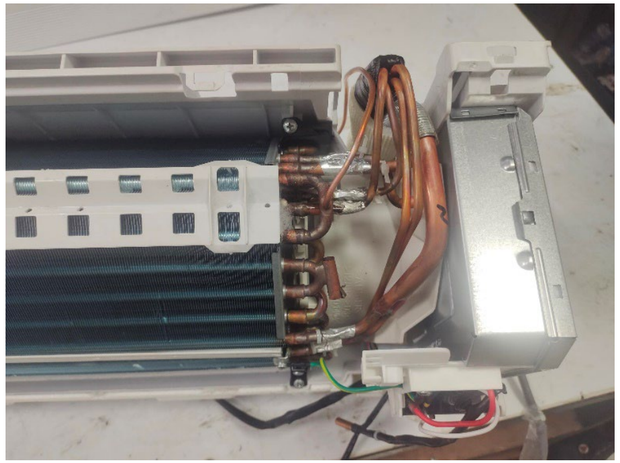
Leak rate tests

Necessary to characterise leak rate against hole size

- Rate can be affected by system design, compressor oil quantity, type, etc.

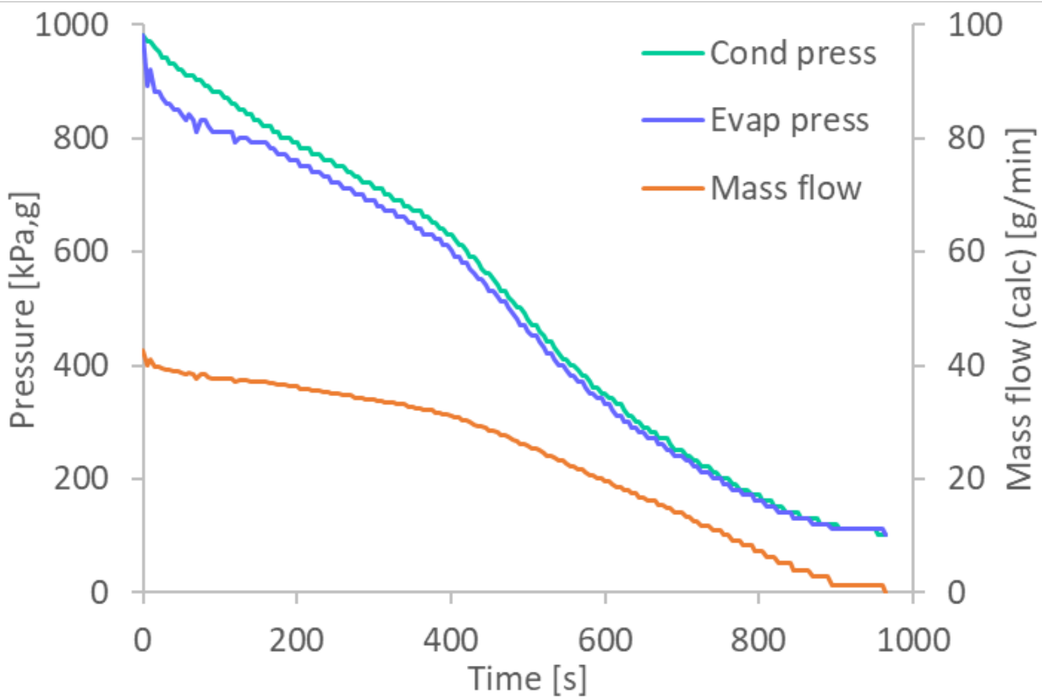
Carried out R290 leak rate tests at Pirangut

- Data used to calibrate system leak model
- IDU, ODU, large and small holes, operating and off
- Used to calibrate leak rate model to cover wide range of hole sizes and operating conditions





Example measurement for 0.29 mm^2 in IDU when off



Leak simulation/concentration tests

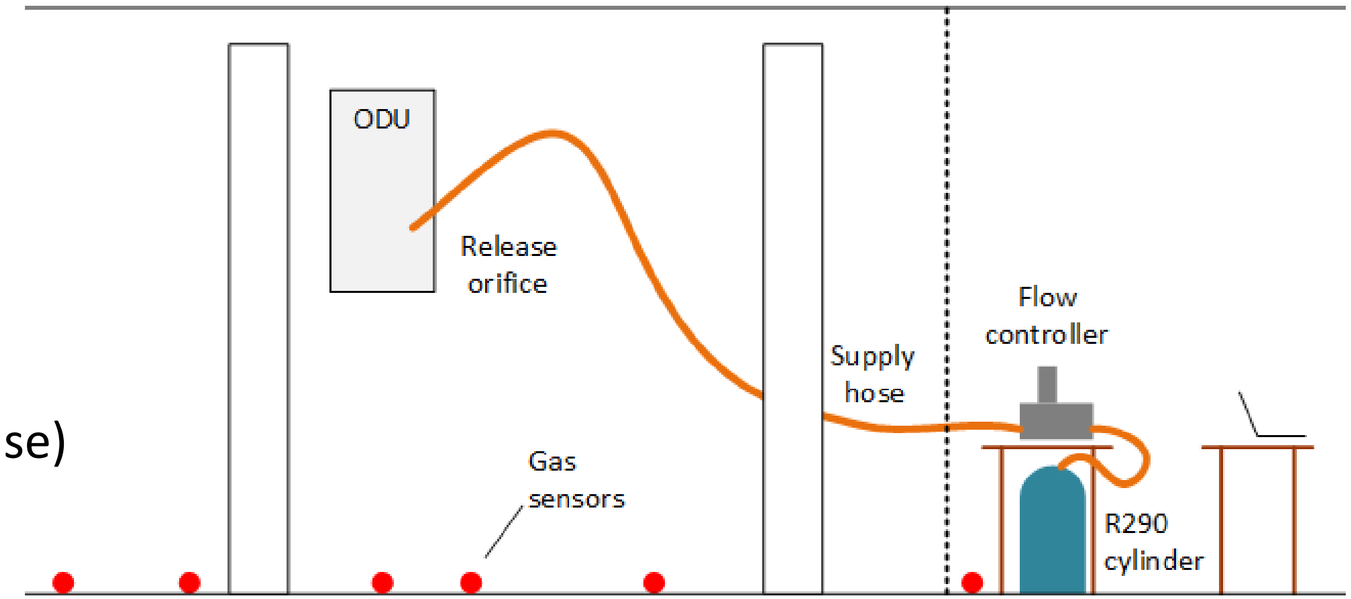
R290 leak simulation tests at Vikhroli

- Obtain concentration data for different situations, applicable to QRA
- Set-up according to local (Indian) conditions
- Approx. 50 tests over one week

Tested

- ODU against an external wall, ground level, elevated, in mock balcony
- ODU in a box, amongst other boxes (warehouse)
- IDU in a closed room
- IDU and ODU fans on and off

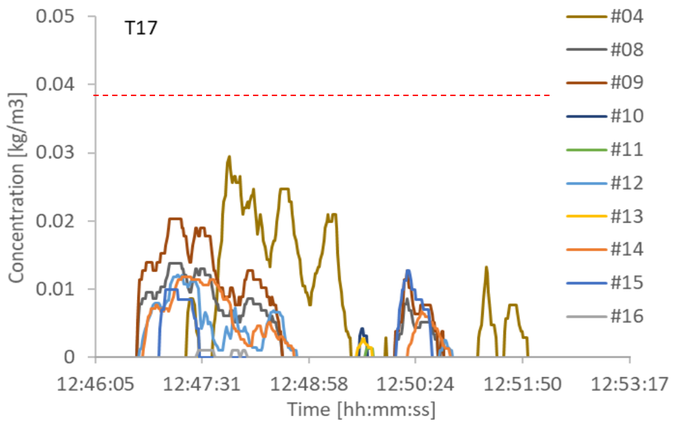
Leak mass flows 10 to 400 g/min



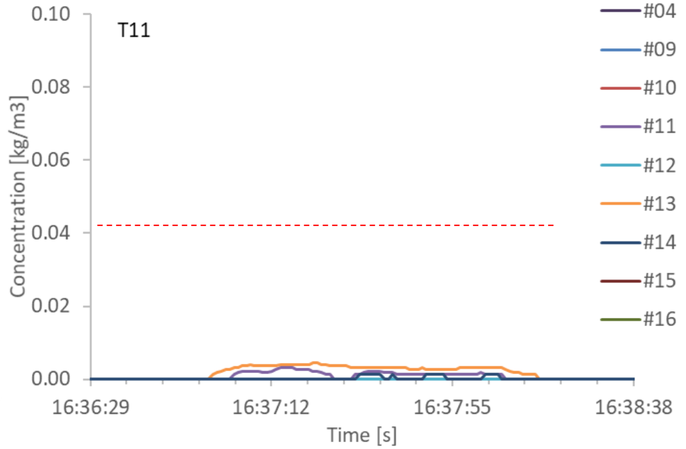
Leak simulation/concentration tests

Releases from ODUs against wall





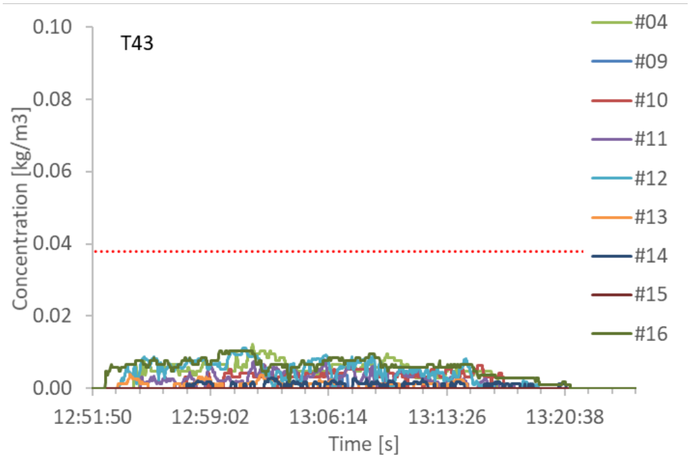
90 g/min, elevated



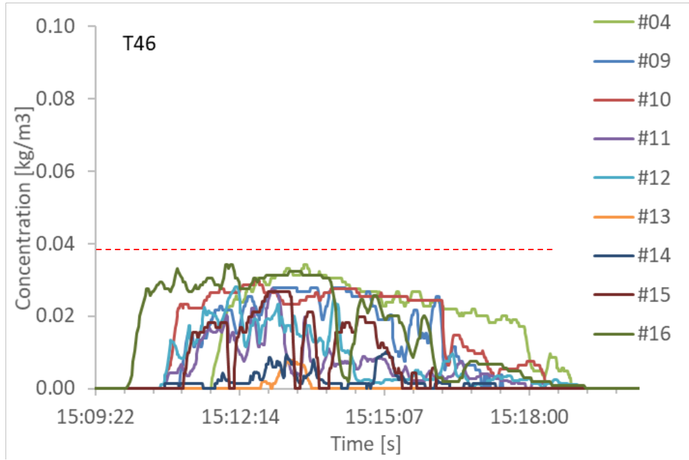
360 g/min, floor, condenser fan on

Releases from ODUs in mock balcony (open and closed)





20 g/min, elevated, cond ret bend

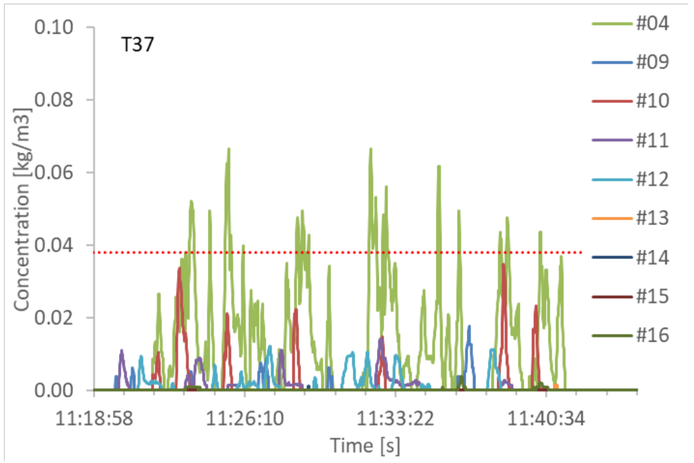


180 g/min, elevated, cond ret bend

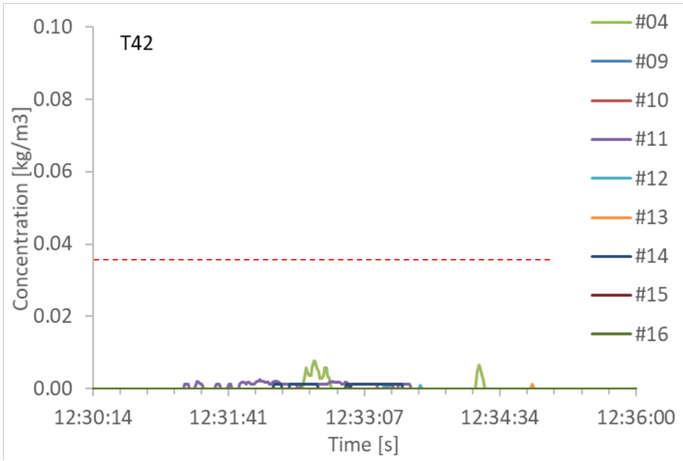
Leak simulation/concentration tests

Releases from boxed ODUs





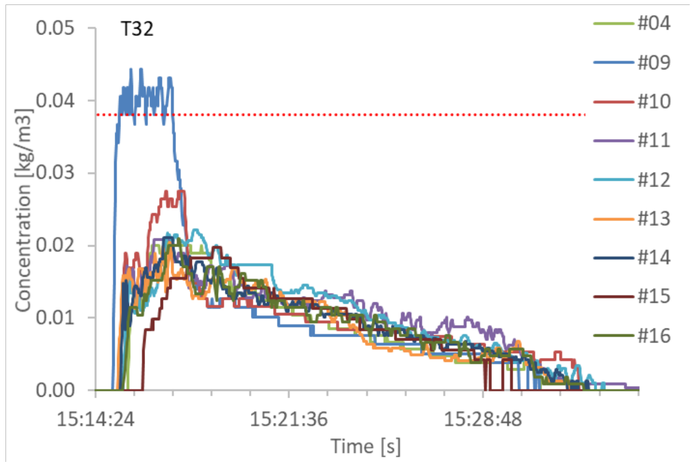
20 g/min



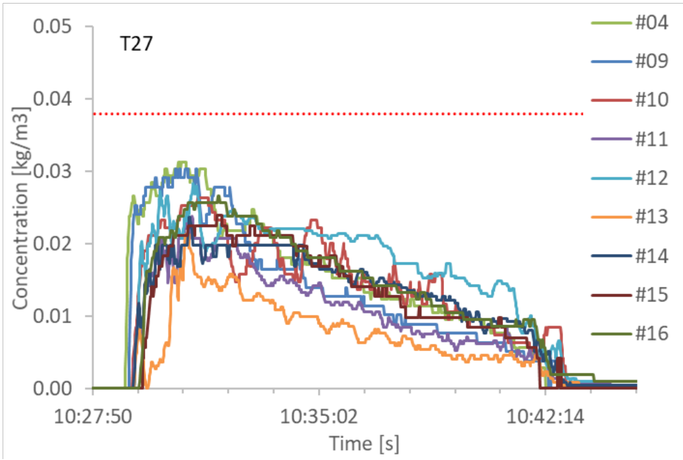
180 g/min, area fans on

Releases from IDU within confined room





180 g/min, from rear connector



180 g/min, from evap return bends, louvre flap closed

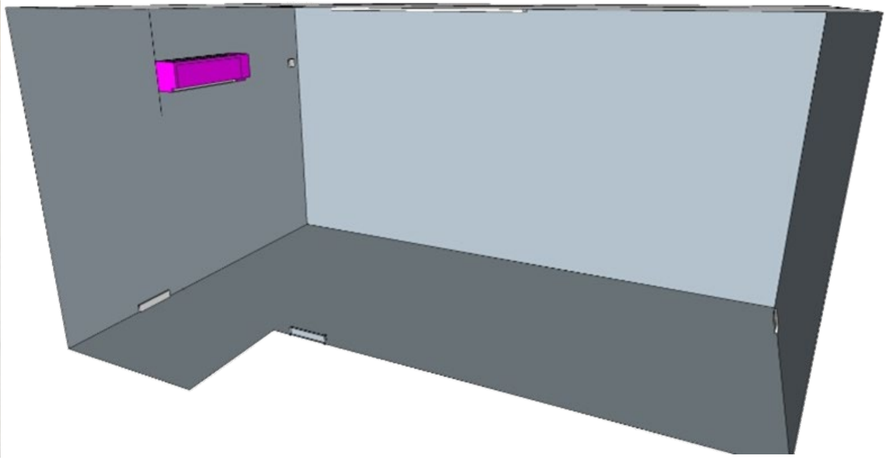
CFD calculations

CFD calculations used to generate flammable quantity data

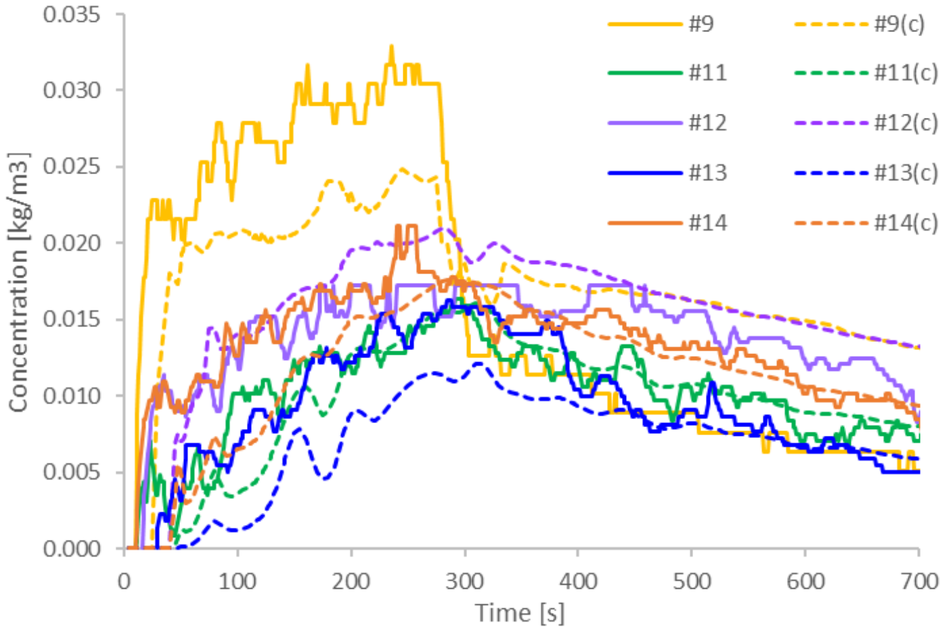
- Flammable volume
- Flammable mass
- Flammable time

CFD model validated against leak simulation tests at Vikhroli





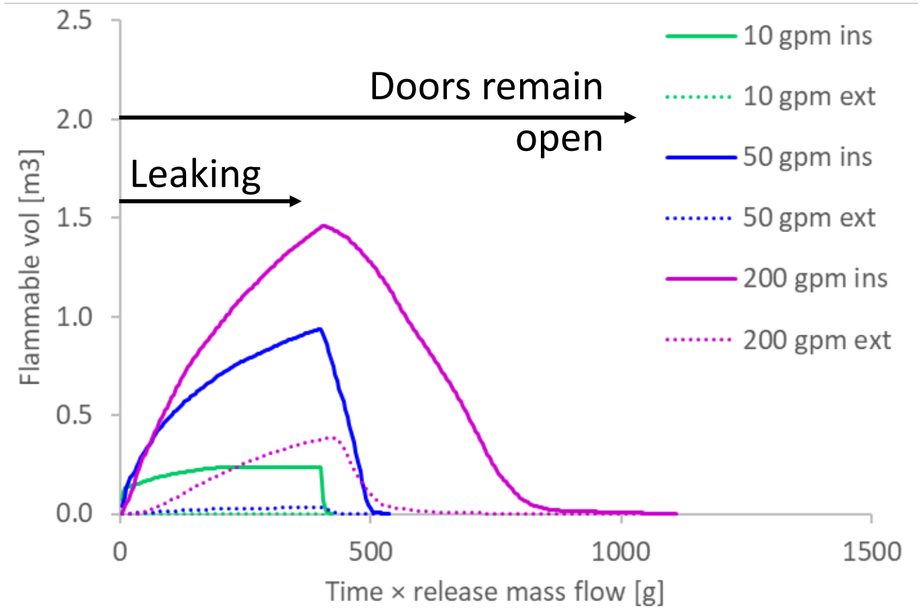
E.g., test no. 27: Release from IDU coil return bends, 180 g/min, 400 g, fans off, doors closed



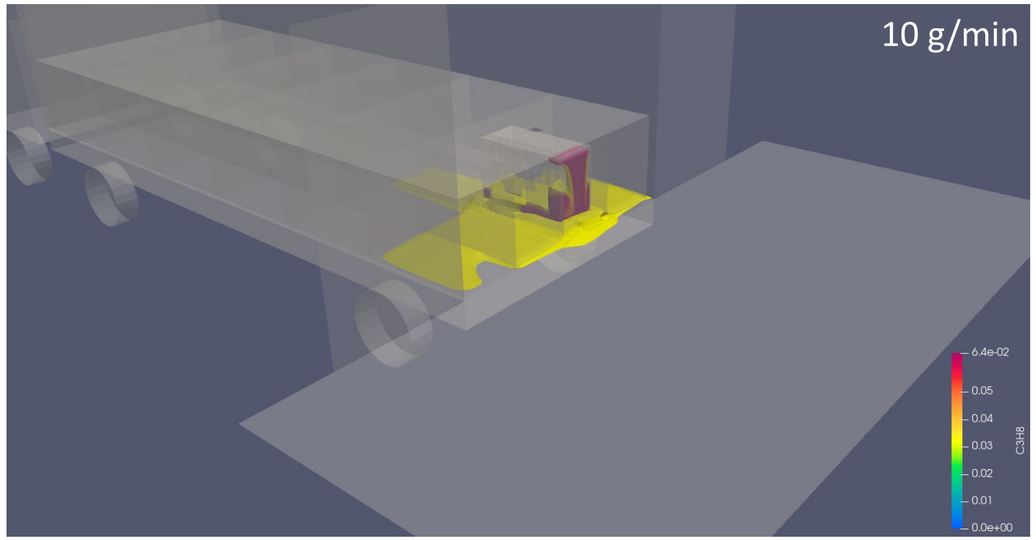
CFD – transport (loading)

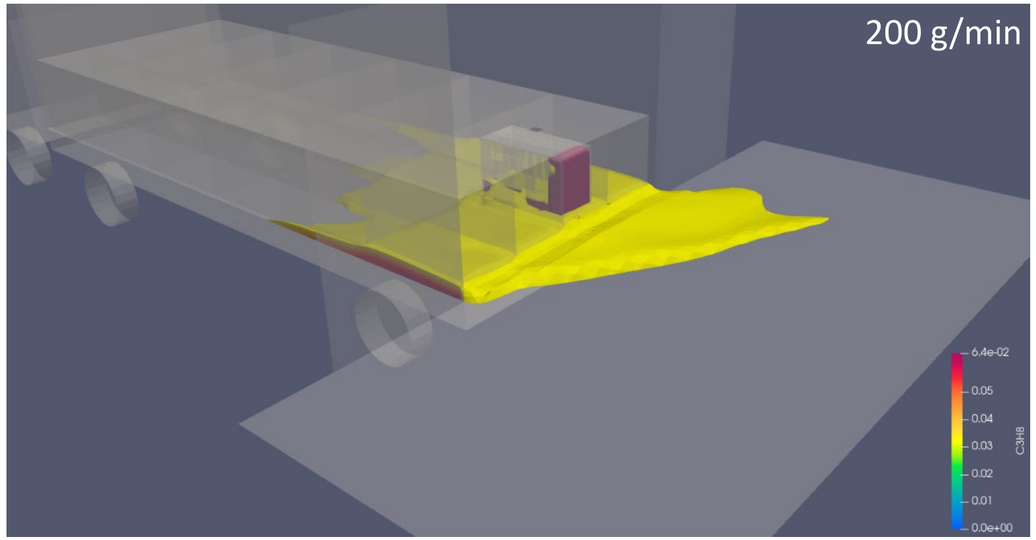
For “loading”

- Driving speed is not relevant for loading
- Movement of workers is neglected, which would ordinarily significantly disperse mixtures
- Cross-wind of 0.25 m/s
- External mixture almost negligible compared to inside, except for 200 g/min







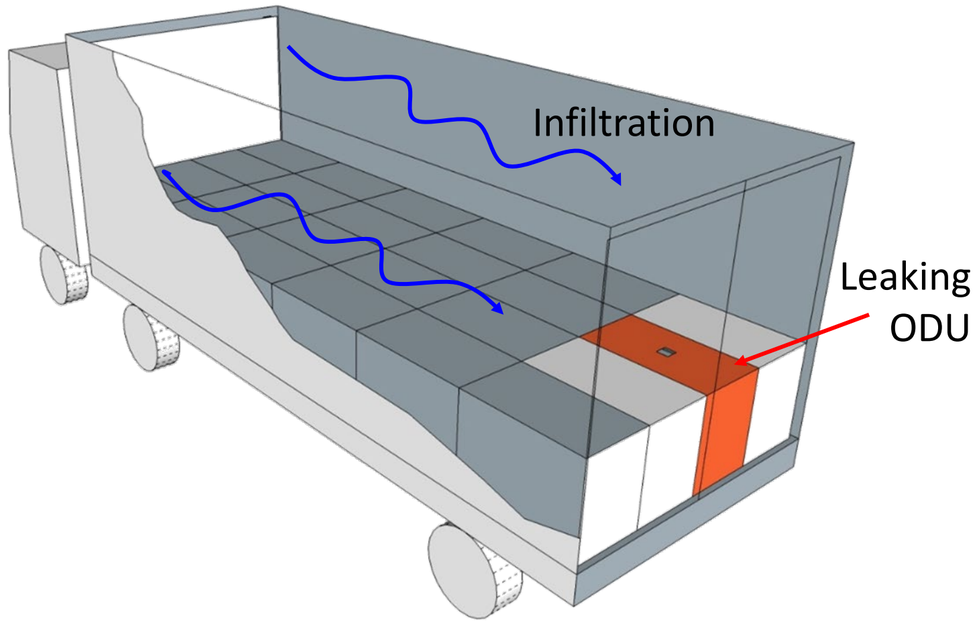


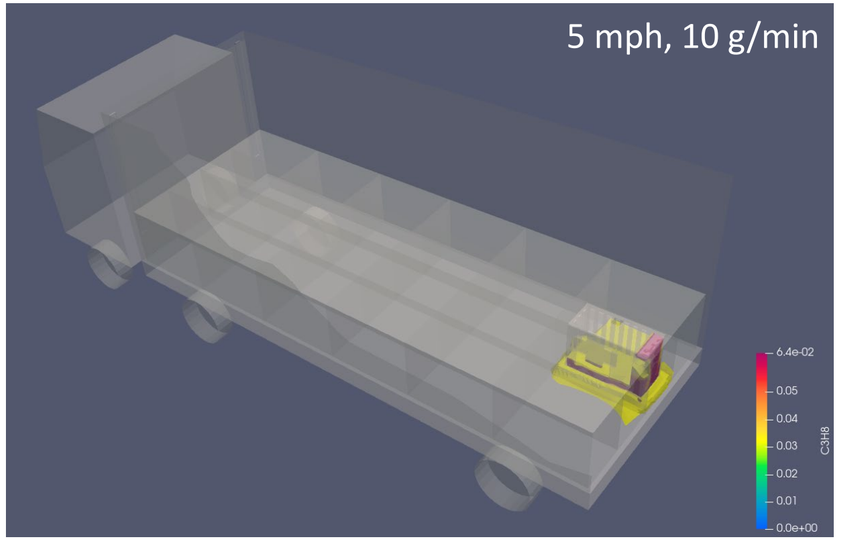
CFD – transport (transit)

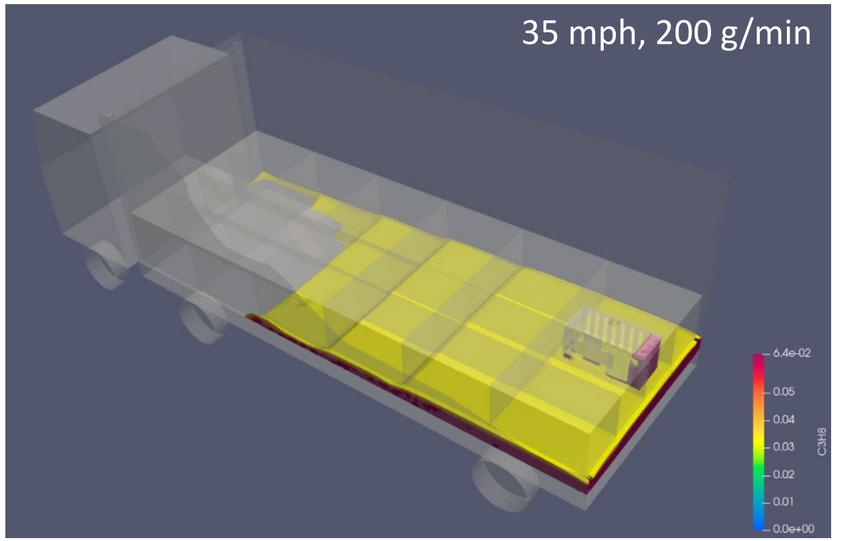
For in-transit

- Doors remain closed
- But gaps in cargo space allow infiltration/flow through of air when driving
- Consider both congested (5 mph) and average speed (35 mph)





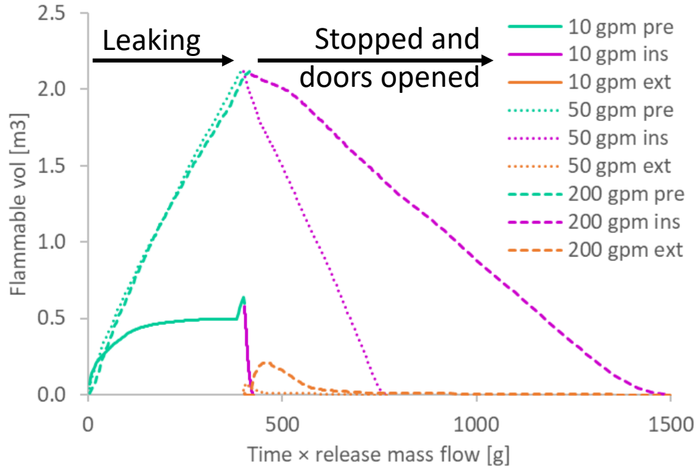




CFD – transport (unloading)

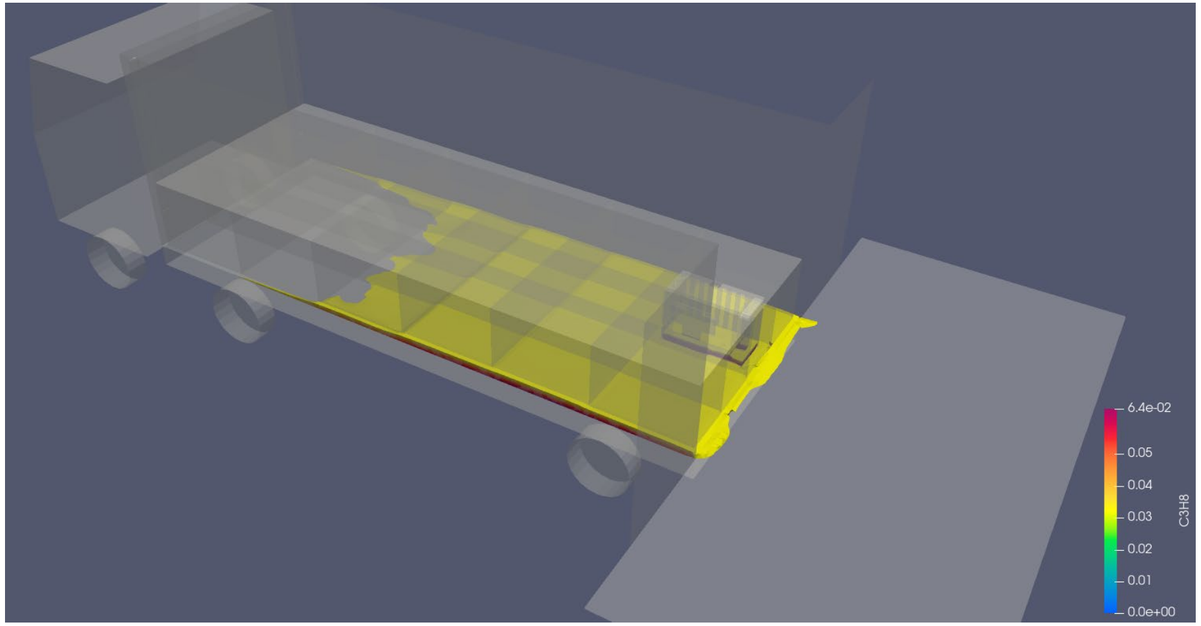
For unloading

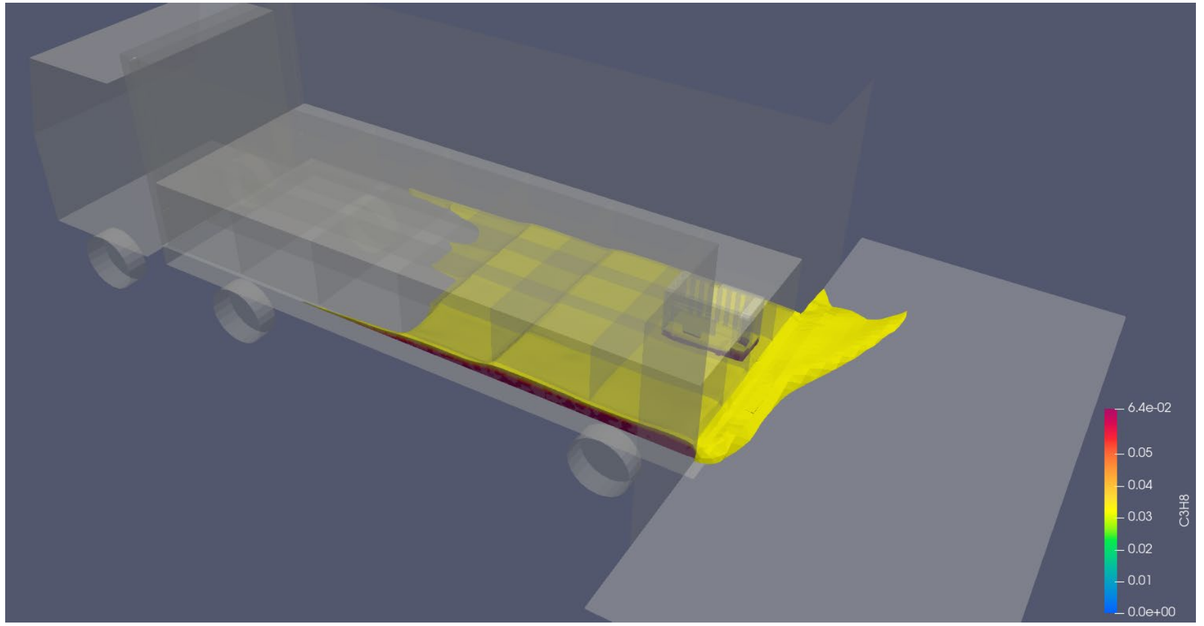
- Leaking ODU in box closest to door, at floor level of cargo space
- Doors opened at worst possible time – when flammable mixture mass is greatest









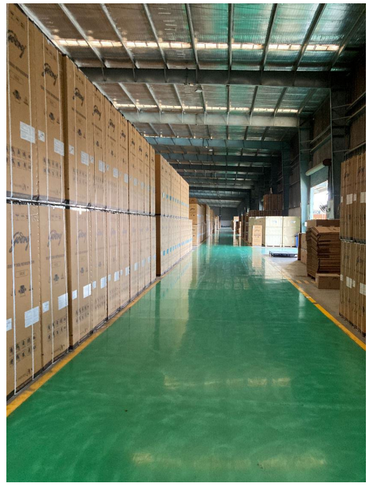


CFD – warehouse storage

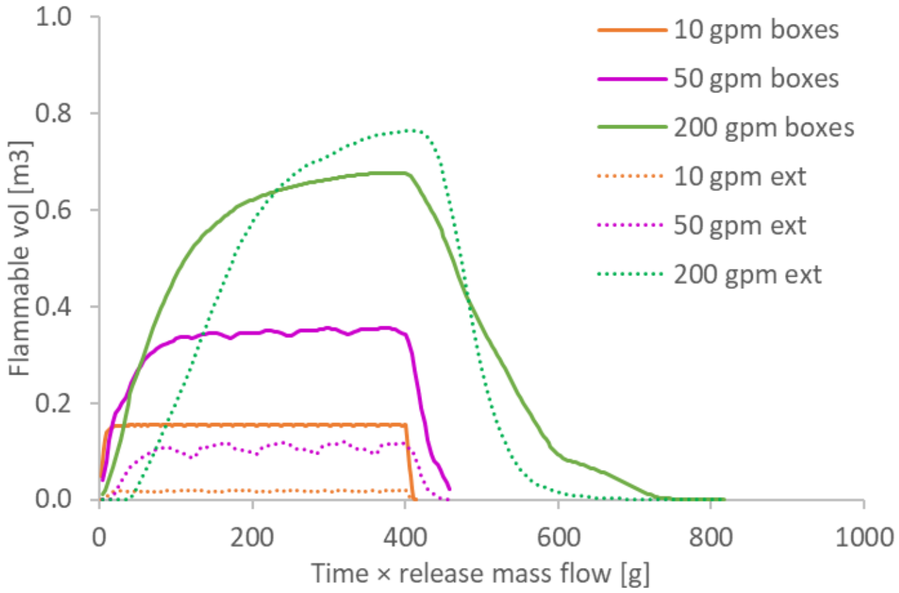
For storage

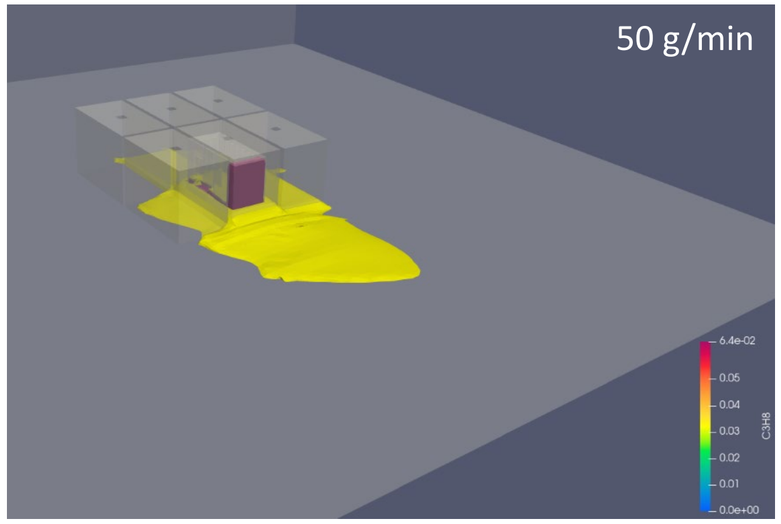
- Spread of mixture across floor potentially considerable (especially for 200 g/min)
- Majority of mixture remains in boxes

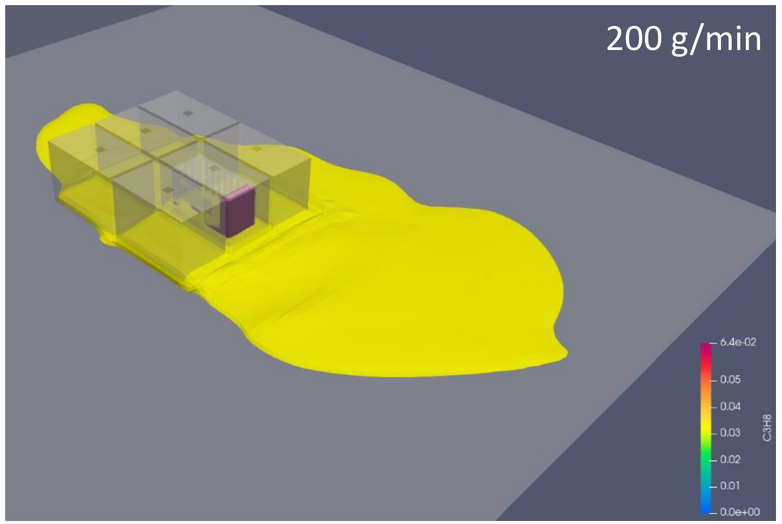








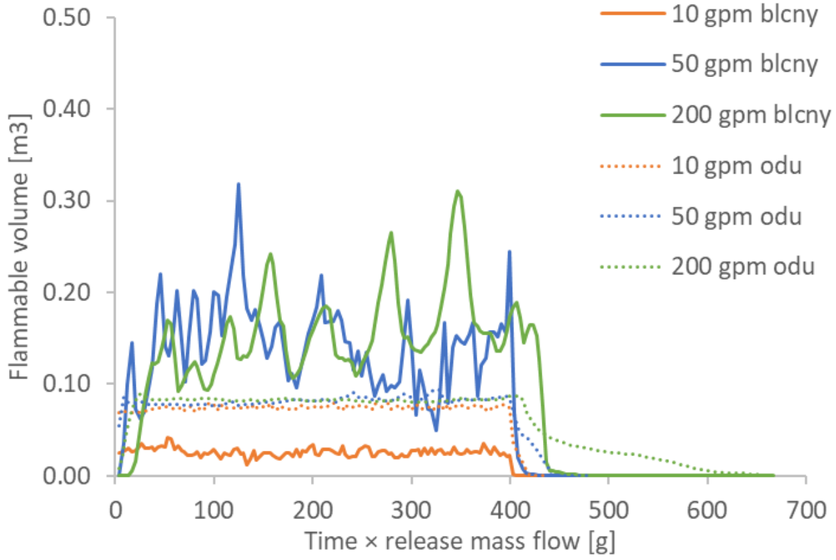


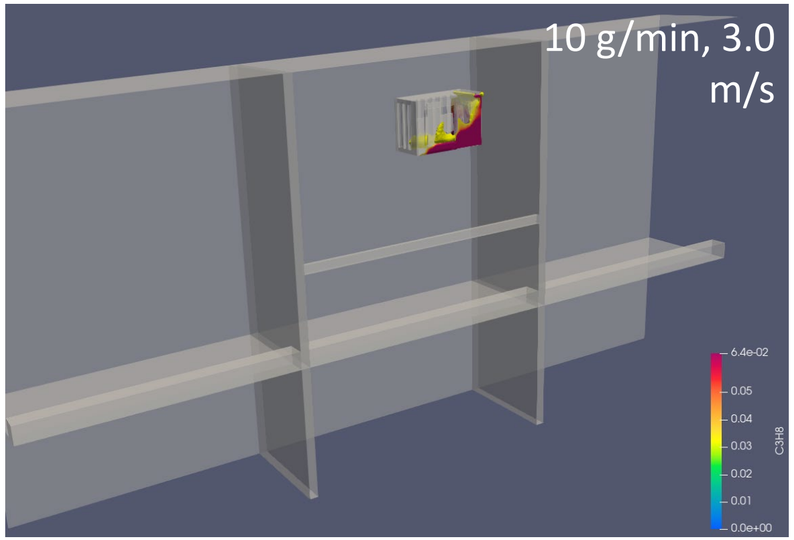


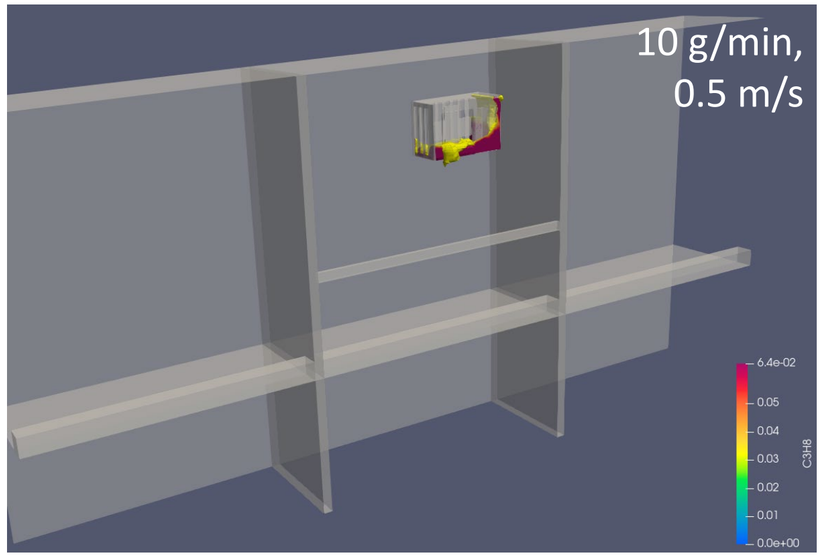
CFD – ODU on balcony

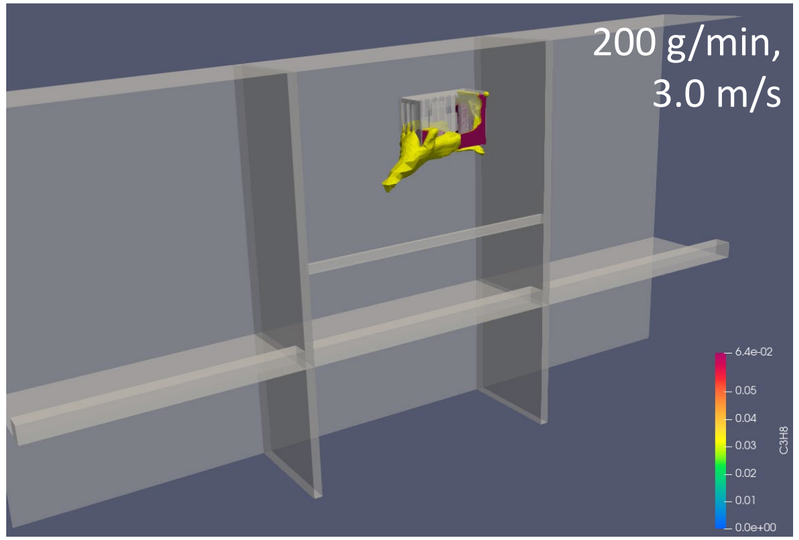
For ODU off and on

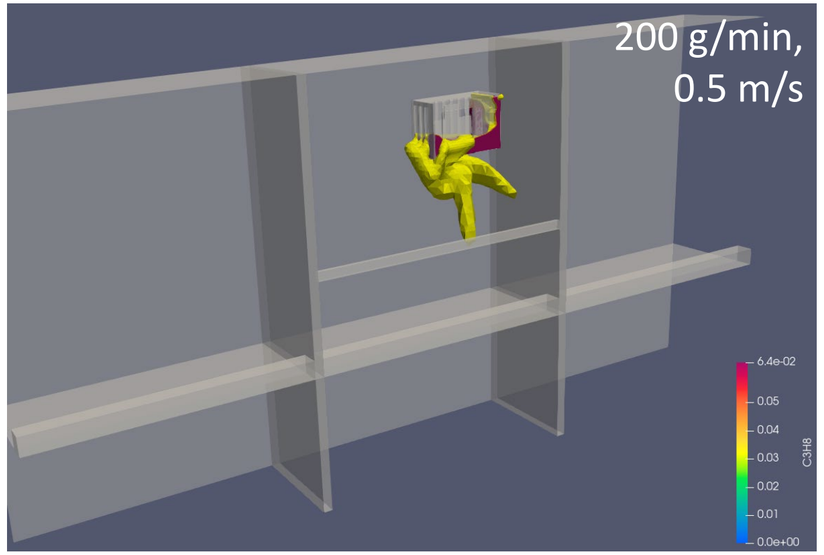
- Two cross-wind speeds
- Balcony otherwise “empty”
- Assumed to be “open”, i.e., no fencing/wall; based on extensive observations
- ODU installed at 1.8 m, to maximise functional space







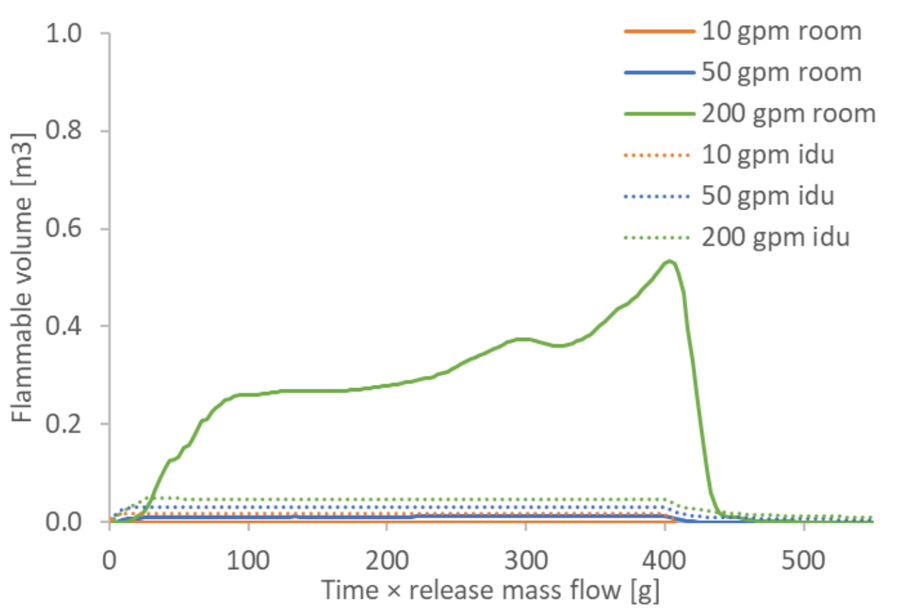


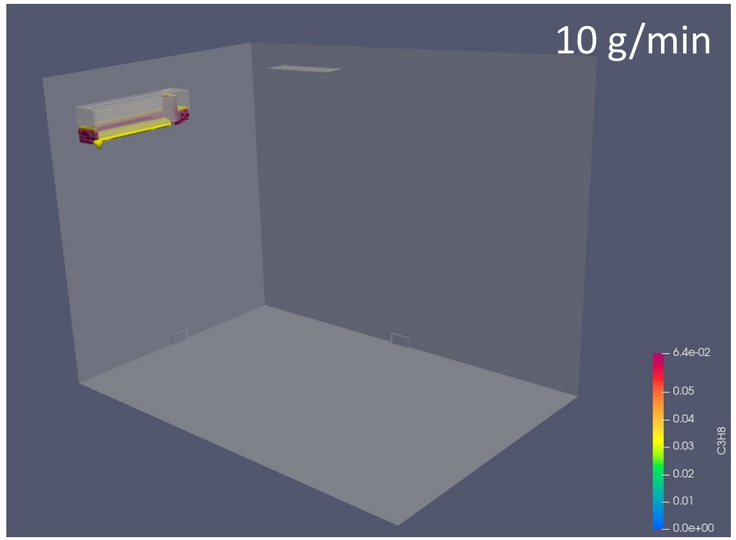


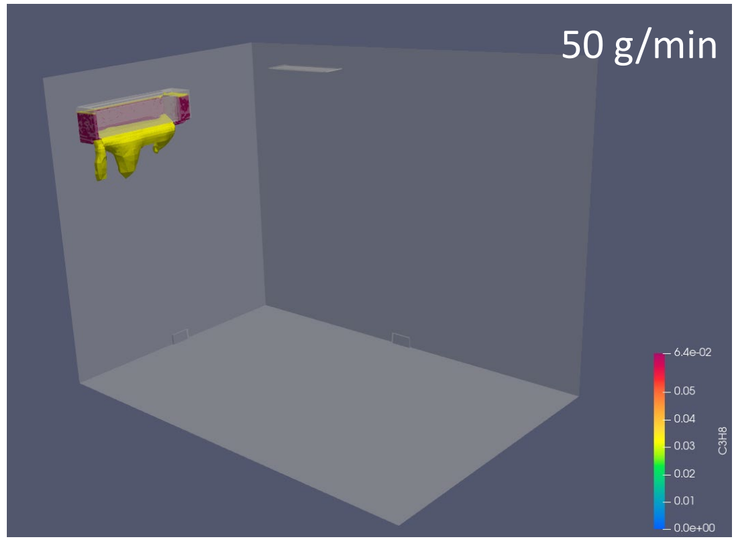
CFD – IDU in room

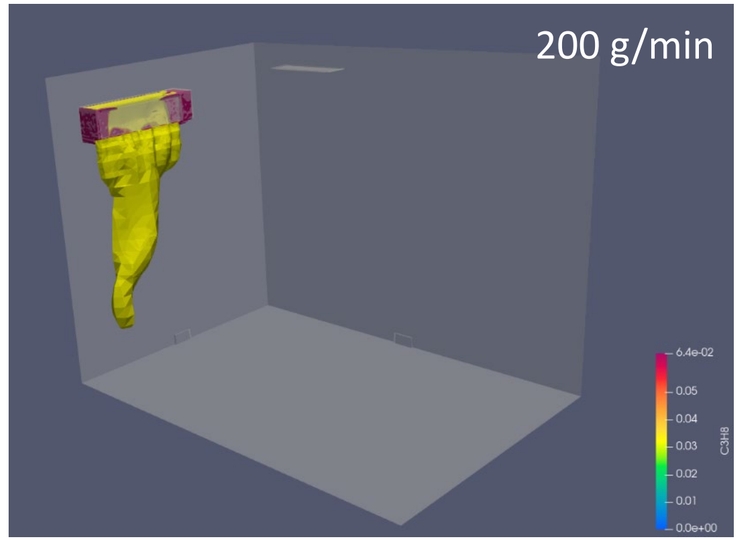
For IDU fan off and on

- For most casers, majority of flammable mixture remains within IDU
- Only with 200 g/min is the mixture volume substantial
- In all cases, mixture entirely dilutes below LFL within a few seconds of cessation of leak
- For fan on, majority of mixture persists within IDU itself





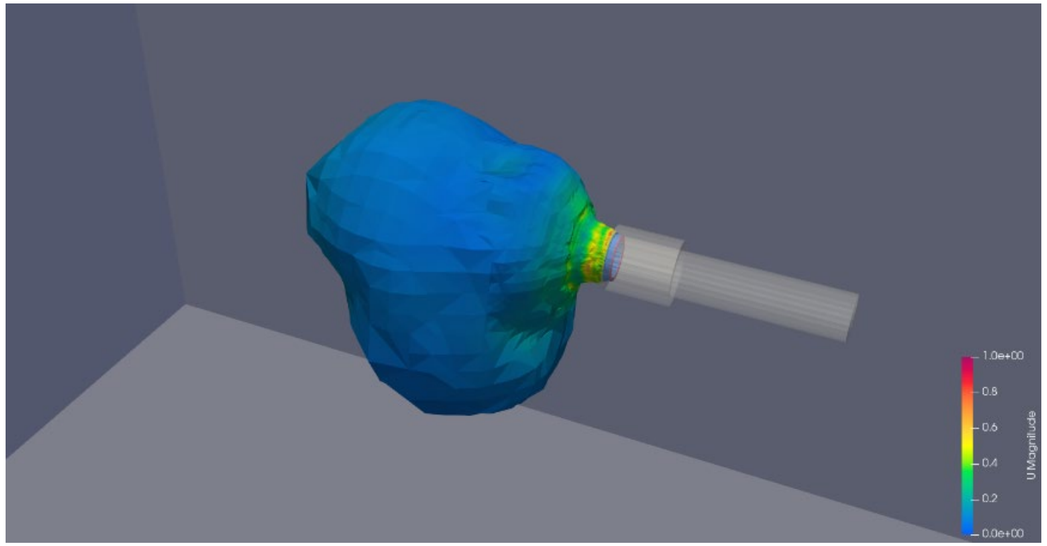




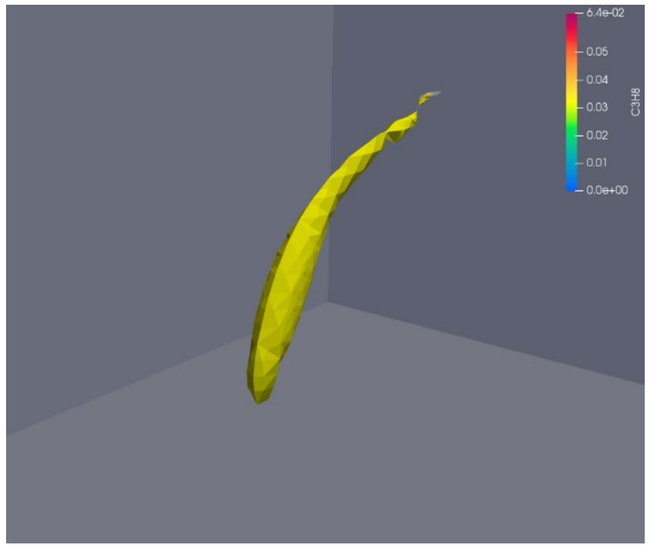
CFD – Service hose/connections

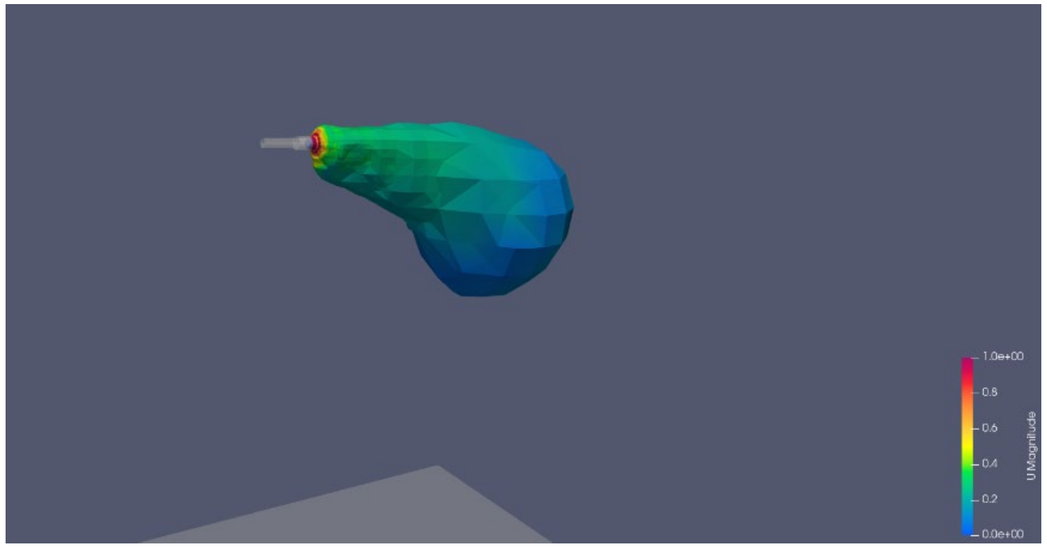
Brief release often occurs when dis/connecting refrigerant hose, during technician refrigerant handling activities

- Carried out practical measurements to estimate range of mass, time and mass flow rate of such releases
- Actual release size and duration highly dependent upon particular case









Potential ignition sources (SOI)

Assumed for living area, balcony, warehouses, un/loading areas, etc.

Below possible release height

- Some intermittent SOIs (e.g., switching), some continuous (e.g. gas hob)

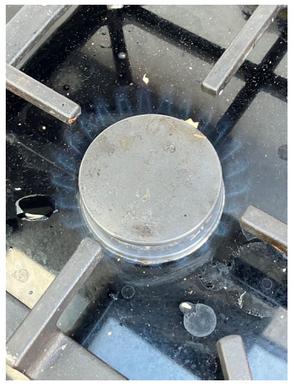
E.g.	Number	Frequency	Duration
Wall sockets	3	4/day	1 s
Washing machine	20 (switch)	0.2/hour	1 s
Gas cooker	1	2/day	1 h

Also electrical faults inside IDU and ODU

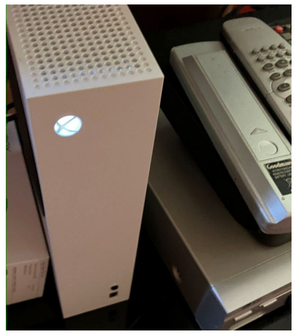
- Faulty components, shorts, damage, etc.

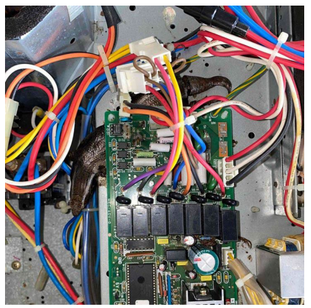
E.g.	Number	Frequency	Duration
Sealed relay fault	5	0.01/year	1 s
Short from damaged cable	60	0.05/year	1 s
Circuit-board overheats	3	0.02/year	20 s













Consequences

Overpressure (“explosion”) and thermal dose (flash fire)

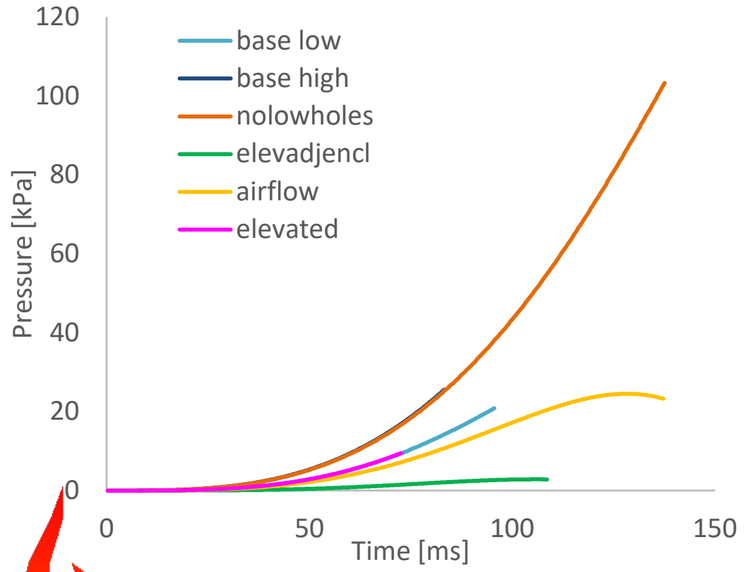
- Calculated from established models

Overpressure

- Used experimental data for validation
- Specific ignition tests involving RAC equipment in confined spaces

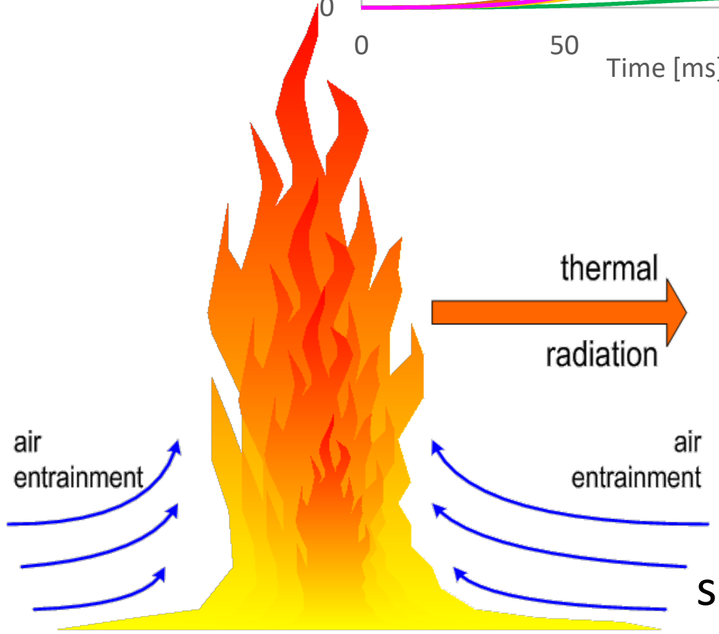
Thermal dose (from flash fire)

- Flame radiates infra-red to surroundings
- Can lead to secondary fires, injury (burns), etc.



Thermal dose [$s(kW/m^2)^{4/3}$]	Effect
115	pain threshold
150	flashover (secondary fire)
1050	1% fatality
6500	99% fatality

Overpressure [kPa]	Effect
2 – 5	Shatters glass
10 – 15	Building damage
100 – 150	Building destroyed



Presence of combustible materials nearby can lead to secondary fire

Outputs

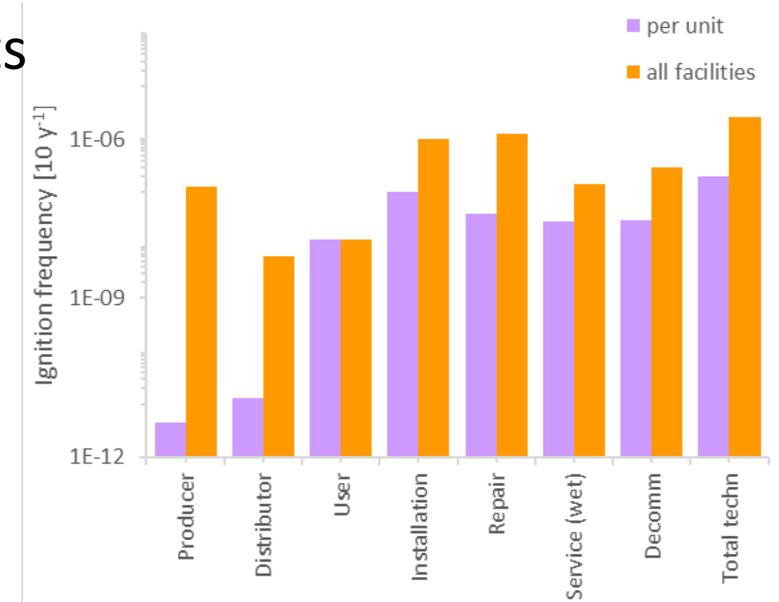
Generated lots of detailed outputs

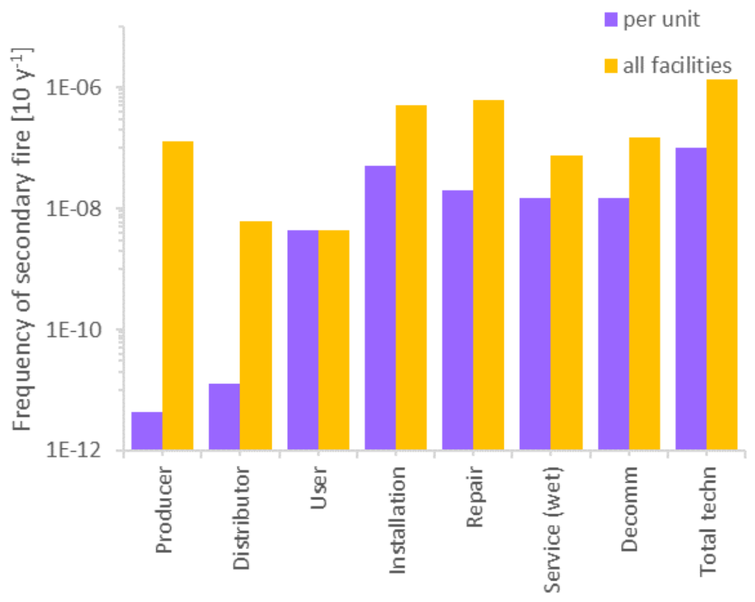
Overall summary

- Includes for maximum overpressure, thermal dose, frequency of injury, fatality, secondary fire, etc.

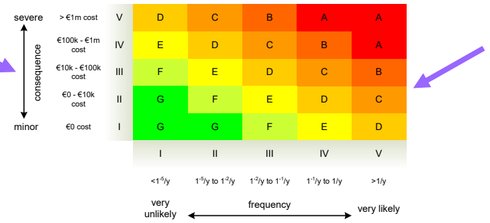
Important to be clear of the context within which values are presented; on the basis of

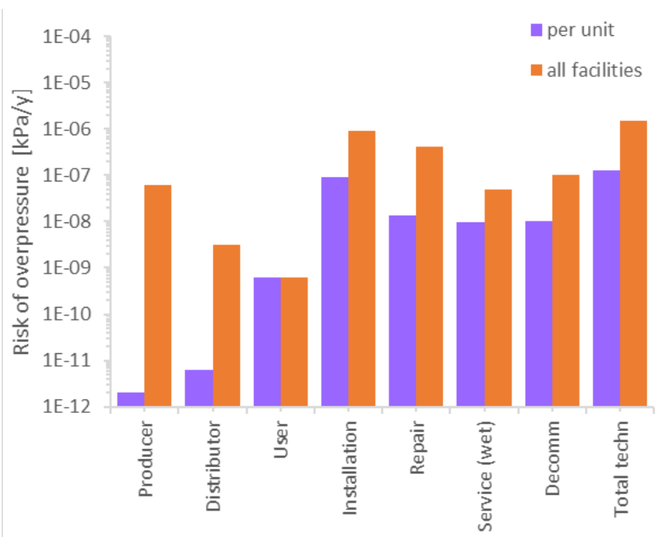
- per AC,
- per location,
- per service visit,
- per technician,
- etc.









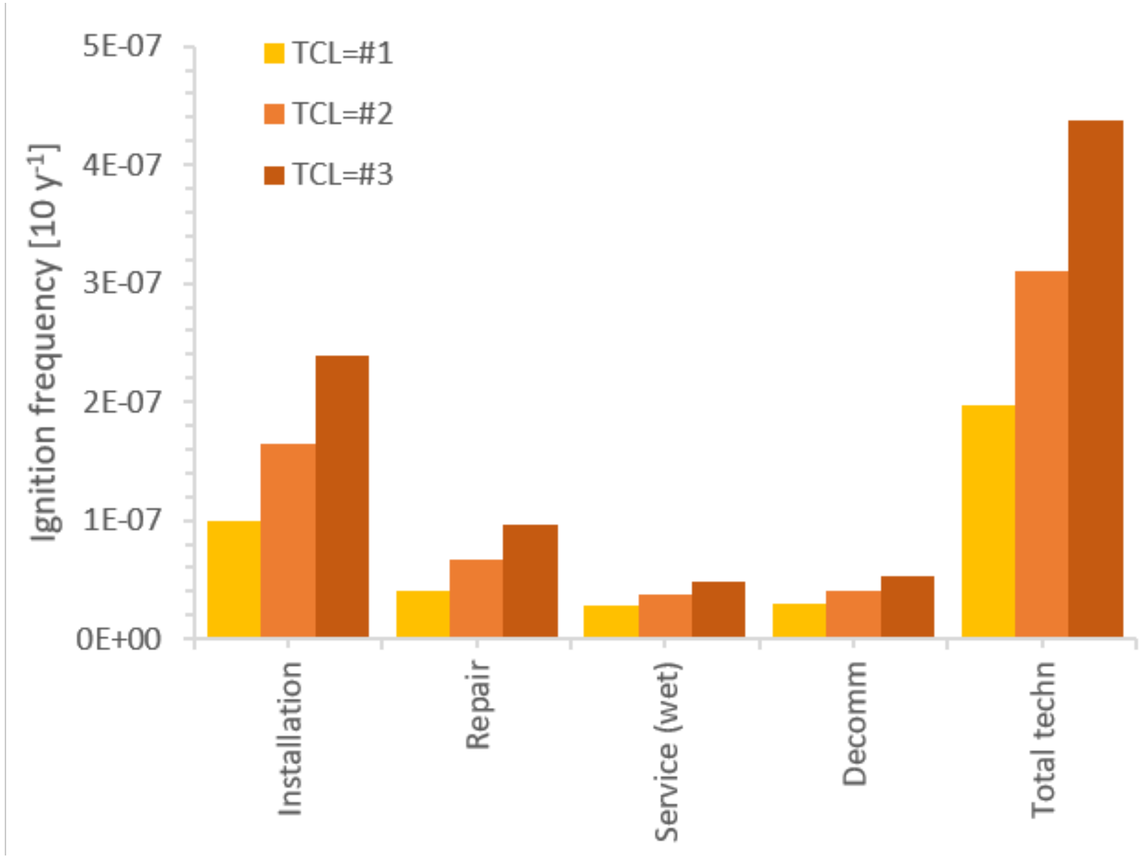


Outputs

For technician activities

- Affected by different assumptions for each set

Percentage of technicians with:		Informal	basic ind training	well trained
OFDN kit	%	30%	50%	80%
Vacuum pump	%	50%	70%	90%
Recovery machine	%	0%	0%	0%
Recovery cylinder	%	0%	0%	0%
Venting hose	%	99%	99%	99%
Gas detector	%	1%	1%	1%
Flare connection tools/set	%	99%	99%	99%
Swage and brazing kit available	%	100%	100%	100%
Pipe cutters	%	100%	100%	100%
Electronic balance	%	15%	15%	80%
Correct (protected) equipment is present (vac pump, d	%	0%	0%	0%
Hoses with stop valves	%	99%	99%	99%
Percentage of technicians that will:				
Only proceed to work under correct circumstances	%	100%	100%	100%
Check tools and equipment are suitable	%	80%	90%	99%
Check working area is suitable, ventilated	%	80%	90%	99%
Ensure all room SOIs are eliminated	%	10%	50%	99%
Will connect hoses well	%	90%	95%	99%
Do strength pressure test	%	10%	50%	99%
Confirm pressure test with visual inspection	%	10%	50%	99%
Confirm pressure test	%	10%	50%	99%
Leak check with soapy water	%	90%	95%	99%

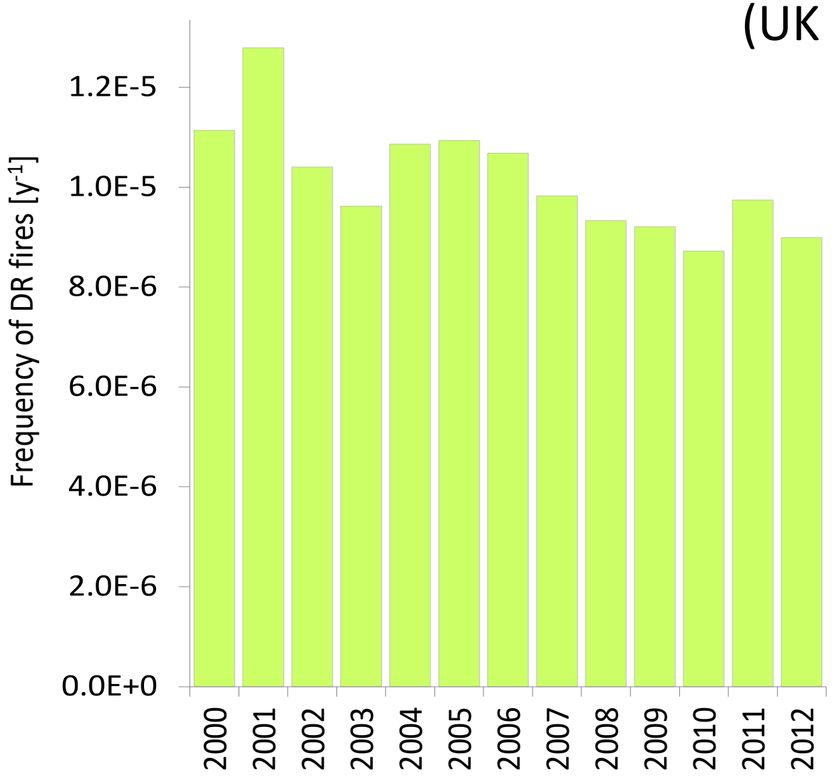


Informal (TCL=#3)

- Doubles likelihood of ignition event compared to well-trained (TCL = #1)

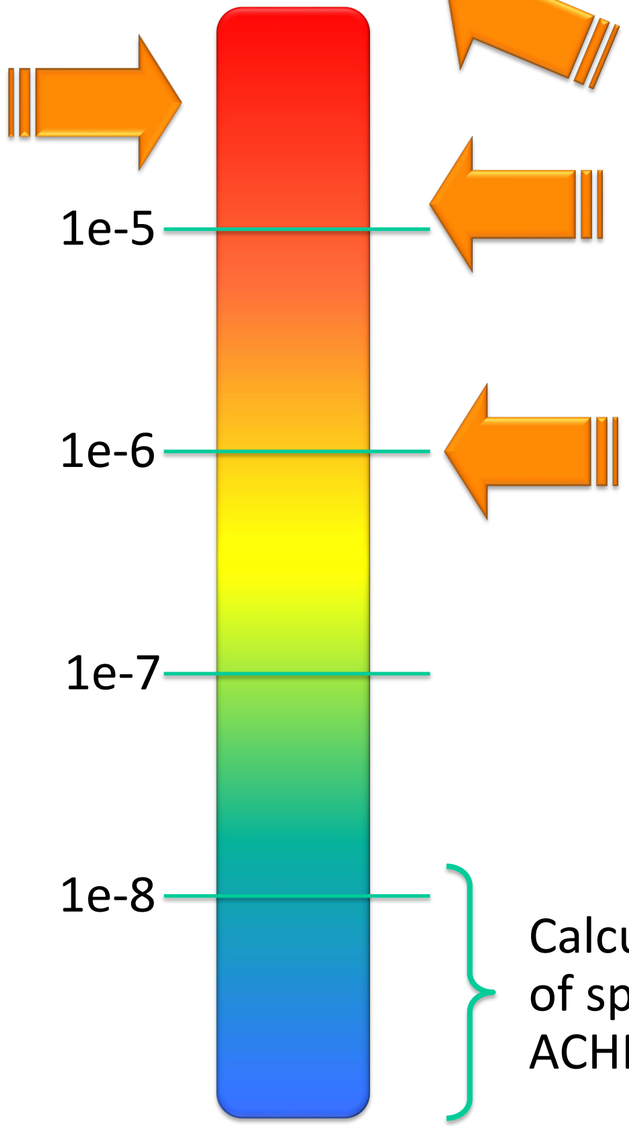
Gauging calculated risk against a baseline

Necessary to compare calculated risk values against established tolerable risks



Frequency of (electrical) fires from domestic fridges (UK)

Limit for workers ~5×10^{-4} (UK HSE)



Non-fatal injury workers, 2.1×10^{-3} (UK), 8.7×10^{-2} y^{-1} (India)

Background fire frequency
ACs (USA): 2×10^{-5} y^{-1}
fridges (UK): 1×10^{-5} y^{-1}

Fatal injury workers, 1.8×10^{-6} (UK), 8.0×10^{-5} y^{-1} (India)

Calculated f^* of split ACHPs

Frequency of sec fire, injury, >10 × lower

Final remarks

Sub-project addressed lifetime flammability risk assessment of Godrej split ACs

- From manufacturer, to installation, to in-use, servicing and end-of-life

Each stage and activity addressed in-depth

- Supported by site visits, activity observations, discussions/interviews, measurements, simulations, analysis
- Vast number of assumptions necessary; ‘realistic’ if high confidence, ‘pessimistic’ if uncertain

Results generated for baseline case, then variations of major input assumptions

Overall

- Producer and distributor stages very low risk – only minimal duration of entire lifetime
- User stage lowest (negligible intervention)
- Technician stages higher (as to be expected)

Results showed that flammability risk is extremely low

- Anecdotal data from field is zero fatalities, zero injuries, zero fires; no systematic official reports from ~1 m R290 split ACs approximately supports this
- Broadly corresponds to QRA results (ignition at << 1×10^{-6} per year)
- Much lower than residual (electrical fire) risk

Thank you for your attention

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Closing

Mr Guntram Glasbrenner

Programme manager, GIZ Proklima