An Introduction to Ammonia Spray Lab Safety and Setup

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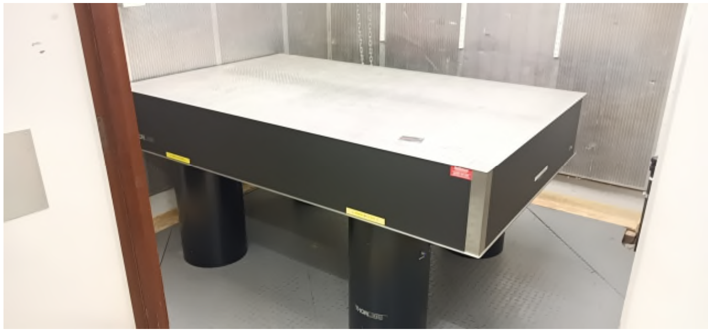
Project scopes and the current task

Project scope

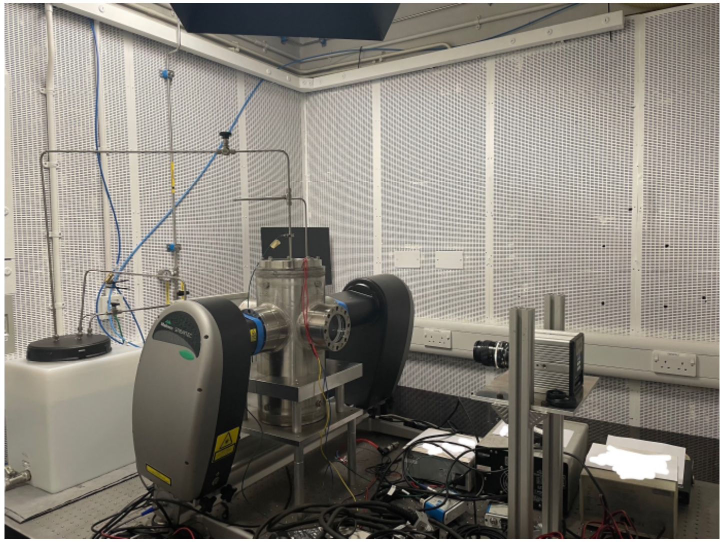
- Fundamental ammonia spray breakup data from experiments
- Mixing data for ammonia-air/nitrogen mixtures
- Simulation of ammonia spray and validation against data from experiments



↑Oxford Ammonia Spray Lab in May 2022

The current task – this presentation

- Build a lab from scratch for ammonia spray tests
- Undertaken safety precautions



↑Oxford Ammonia Spray Lab in June 2023

Ammonia supply

Supply available

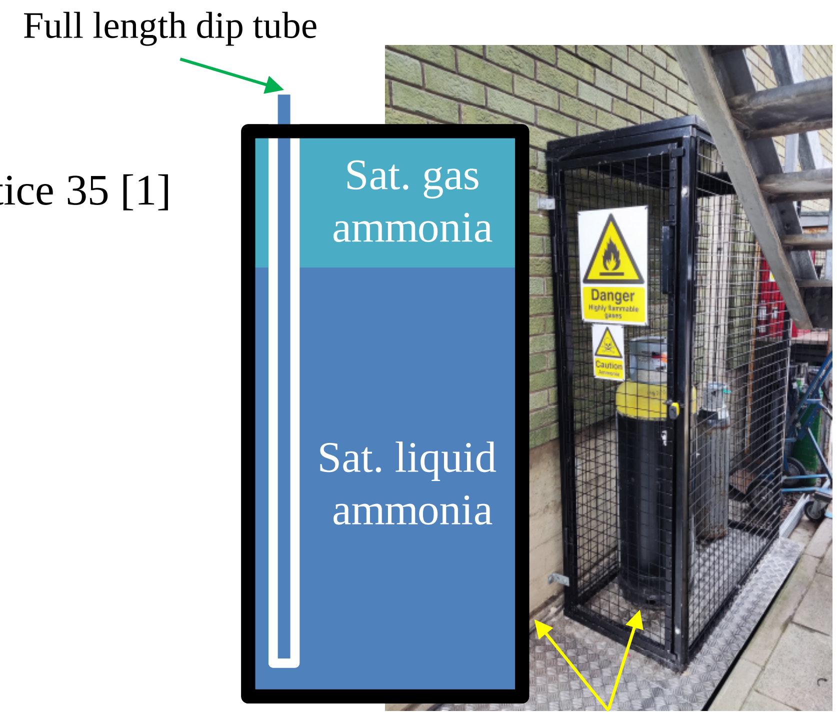
- Saturated liquid-vapour mixture
  - Filling ratio in accordance with the BCGA Code of Practice 35 [1]
  - Cylinder pressure depends on ambient temperature [2]

➢ Best supply available: Saturated liquid

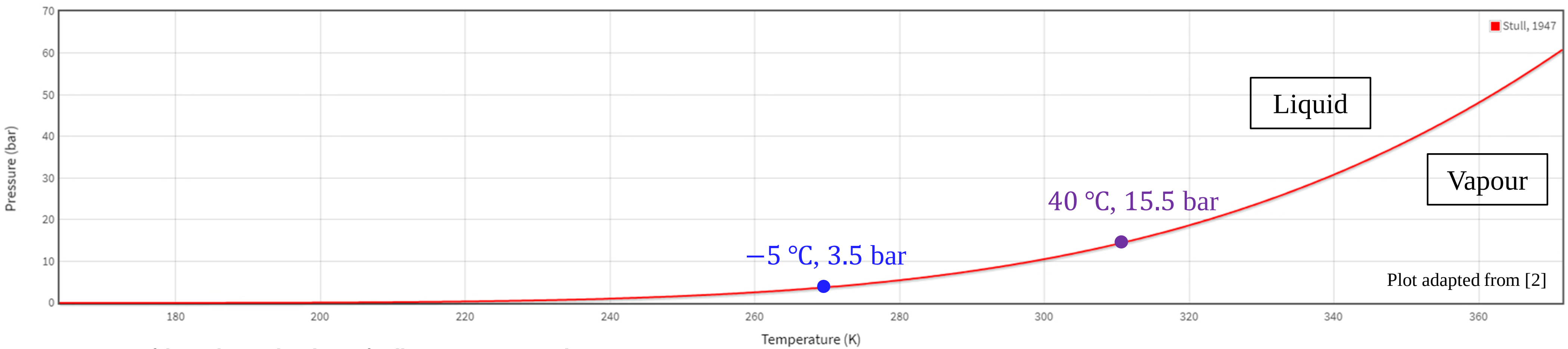
Requirements for ammonia spray tests:

- High injection pressure
- Liquid injection without cavitation

➢ Need an external pressurising system



Ammonia cylinder from BOC



*Locations of the markers in this plot are for illustration purposes only.

Toxicity considerations and ammonia storage

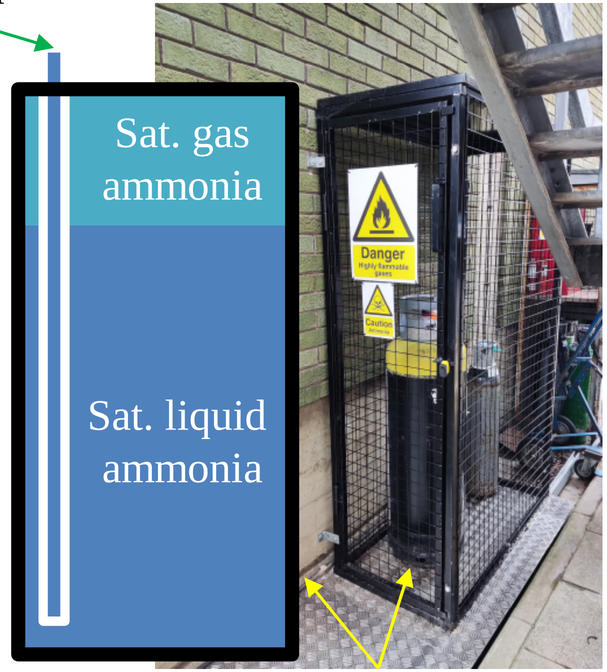
Toxicity considerations

- Workspace exposure limits for anhydrous ammonia [3, 4]
    - Long-Term (8 hours TWA): 25 ppm
    - Short-Term (15 minutes): 35 ppm
- Liquid to vapour expansion ratio for ammonia at room temperature: ~1: 108 by volume [2]

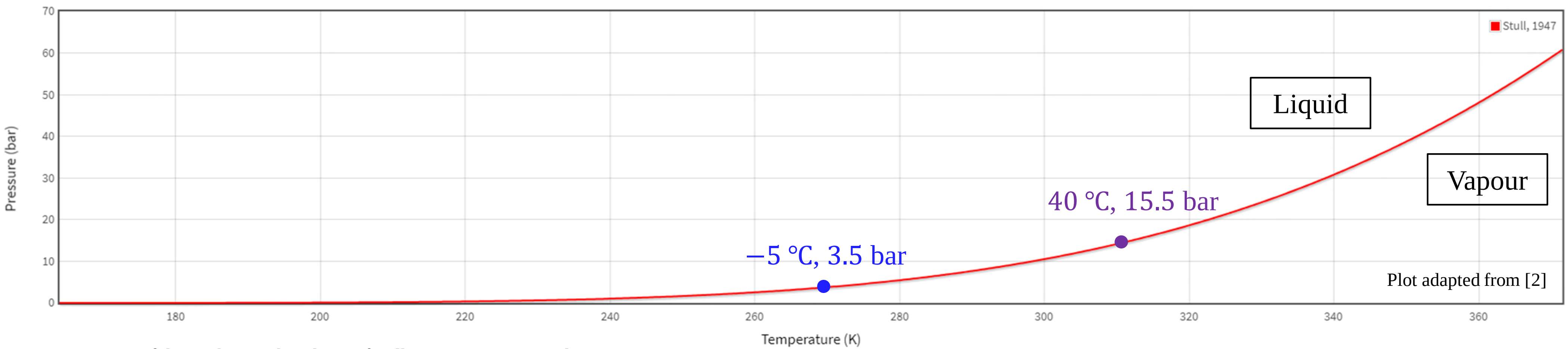
➢ Recommended outdoor storage as per BCGA Code of Practice 18 [5]

➢ Need a liquid ammonia delivery system from outdoor storage to indoor test facilities

Full length dip tube



Ammonia cylinder from BOC



*Locations of the markers in this plot are for illustration purposes only.

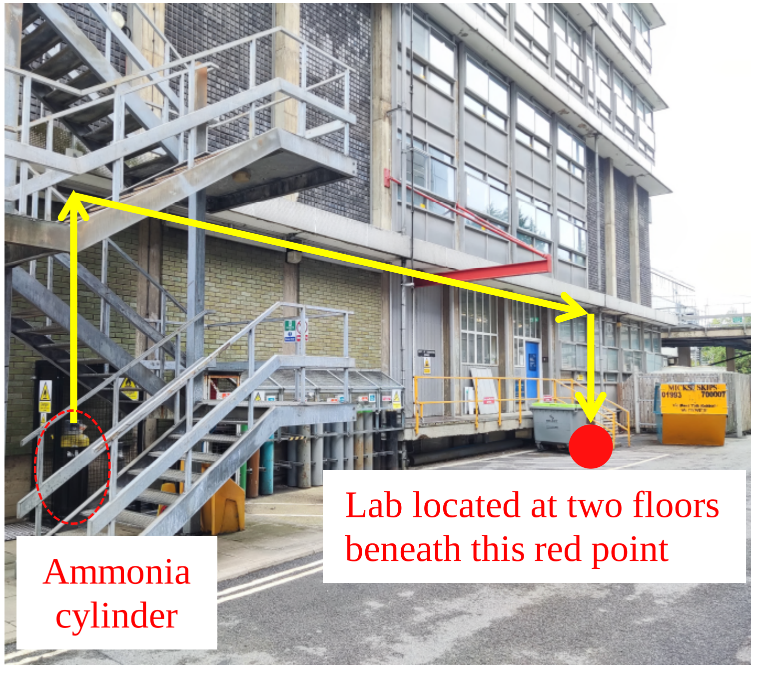
Ammonia delivery challenges

- Chose against portable cylinders to minimise leakage risks during movement and re-connection
- Permanent ammonia delivery pipework (about 60 metres)

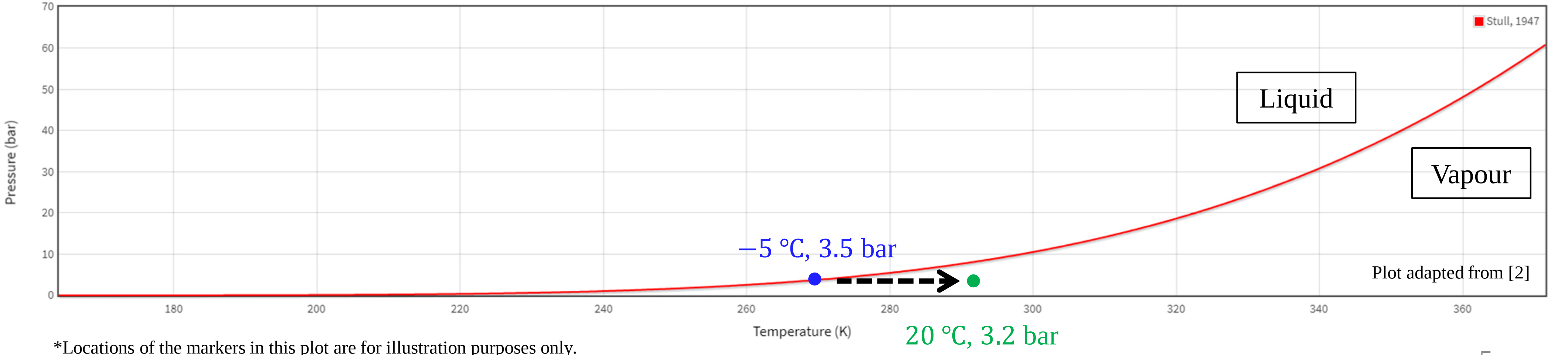
➢ Cavitation and evaporation of ammonia in the pipework
  - o Pressure drop due to frictional loss
  - o Temperature increase due to indoor heating

➢ Complete evaporation at the lab end in cold weathers

➢ Possible solutions:
  - o Thermal insulation of the pipework
  - o Liquefy ammonia at the lab end (accumulator) [6, 7]
  - o Incorporate a pressurising system at the supply end (pump)



↑Engineering Science Building in central Oxford



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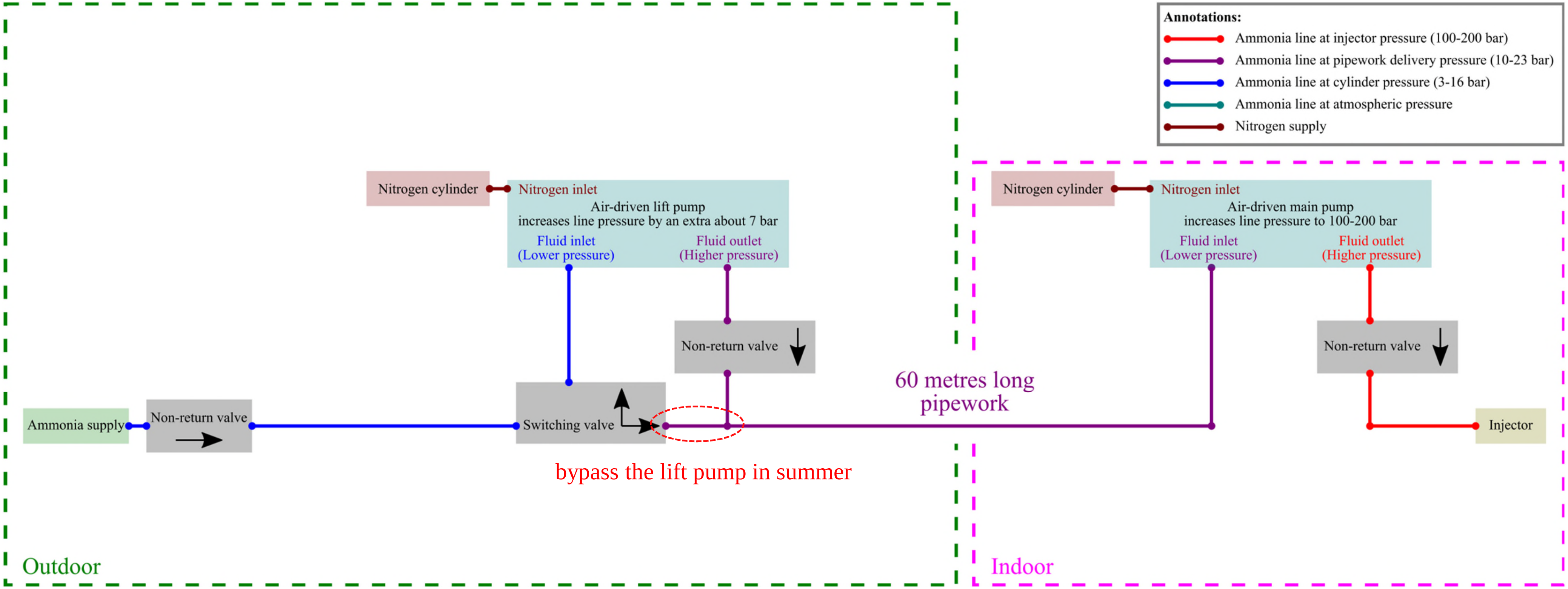
Our solutions to the delivery challenges

- Dual pump design
  - Lift pump: increase pipework delivery pressure by an extra of 7 bar from cylinder pressure
  - Main pump: further increase liquid ammonia pressure to injector pressure

➢ Maintains a suitable in-line pressure for the lengthy pipework

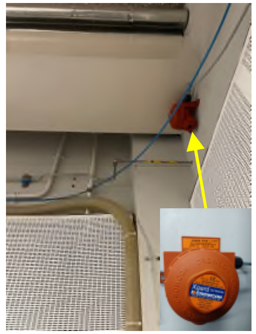
➢ Offers a continuous liquid ammonia supply

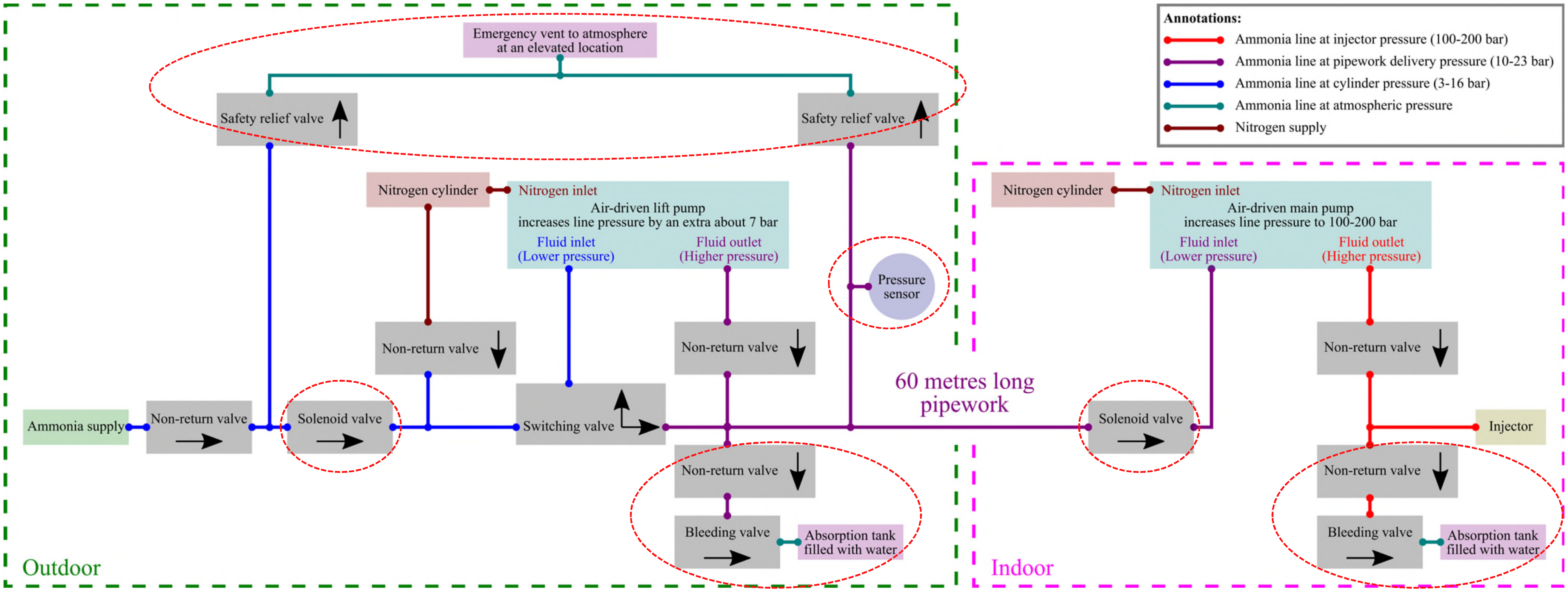
➢ Limits amount of ammonia indoors (small bore pipework, ~5.5 mm in diameter)



Safety features included

- Multiple venting points and options
  - Safety relief valve triggered at pre-set pressures: to atmosphere at an elevated location (emergency)
  - Manually operated bleeding valves: bubble through water (main)
- Ammonia-water solution sealed and disposed in UN certified containers
- Ammonia and in-line pressure sensors for leakage detection
- Solenoid valve power supply interlocks with leakage detection sensors





Summary and future work

- Ammonia supply as a saturation liquid only
  - Temperature dependent supply pressure
  - Lower supply pressure than required
- Toxicity considerations
  - Outdoor cylinder storage
  - Lengthy delivery pipework
- Challenges found: cavitation or even complete evaporation in pipework
- Solutions proposed: dual pump design
- Safety features
  - Emergency safety relief valve at pre-set pressures
  - Bubble waste ammonia into water and dispose resulting alkaline solutions
  - Ammonia and in-line pressure sensors for leakage detection
  - Solenoid valve power supply interlocks with leakage detection sensors

*These experiences and lessons learned can be extended to other applications.

Acknowledgements and References

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  - Mr. Ronan Pelé from University of Orléans, France

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Plot available at NIST database: https://webbook.nist.gov/cgi/inchi?ID=C7664417&Mask=4&Type=ANTOINE&Plot=on#ANTOINE

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