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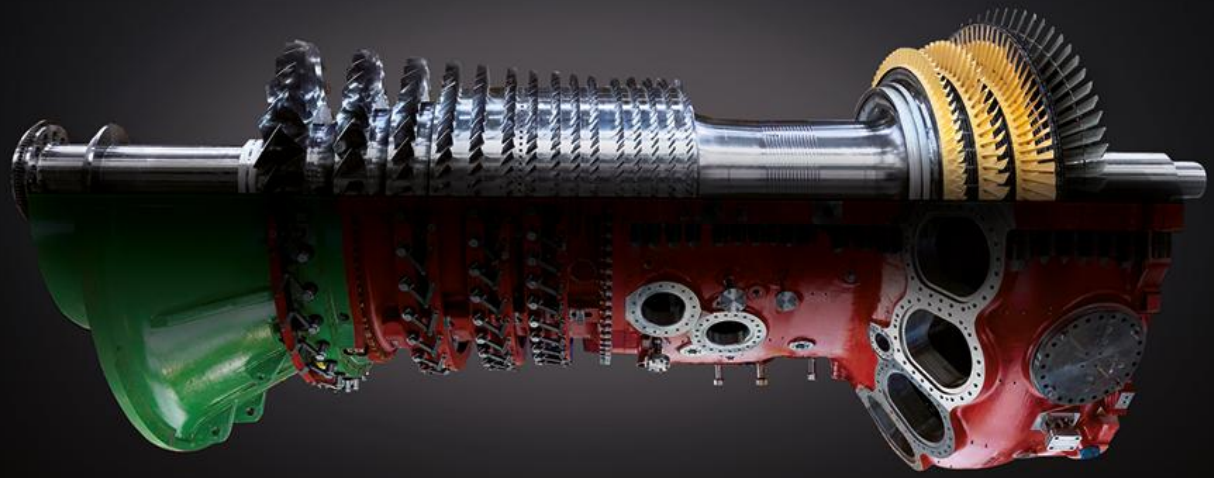

Hydrogen GT Enclosure open issues for operation

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Bergen, 26.03.2025

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Targets for H2 readiness

The target of the study was to find a way to operate the GT enclosure safely on hydrogen with the lowest possible costs for the entire project.

This attempts were made to achieve this only by changing the ventilation installation.

Safety standards:

UK Health and safety code PM84, augmented by HSE publications CM/04/09
IEC60079-10-1
NFPA497 / NFPA2
ISO 21789

(All norms and standard documents are still written for methane.
These norms for H2 are currently under development.)

Boundary conditions for a save operation of the enclosure (used for the CFD Study):

- A gas leakage through a hole between 0.25 – 25 mm^2 has to be considered (worst case scenario to be considered)
- The size of a gas cloud (100% LEL) in such event should not exceed 1 m^3

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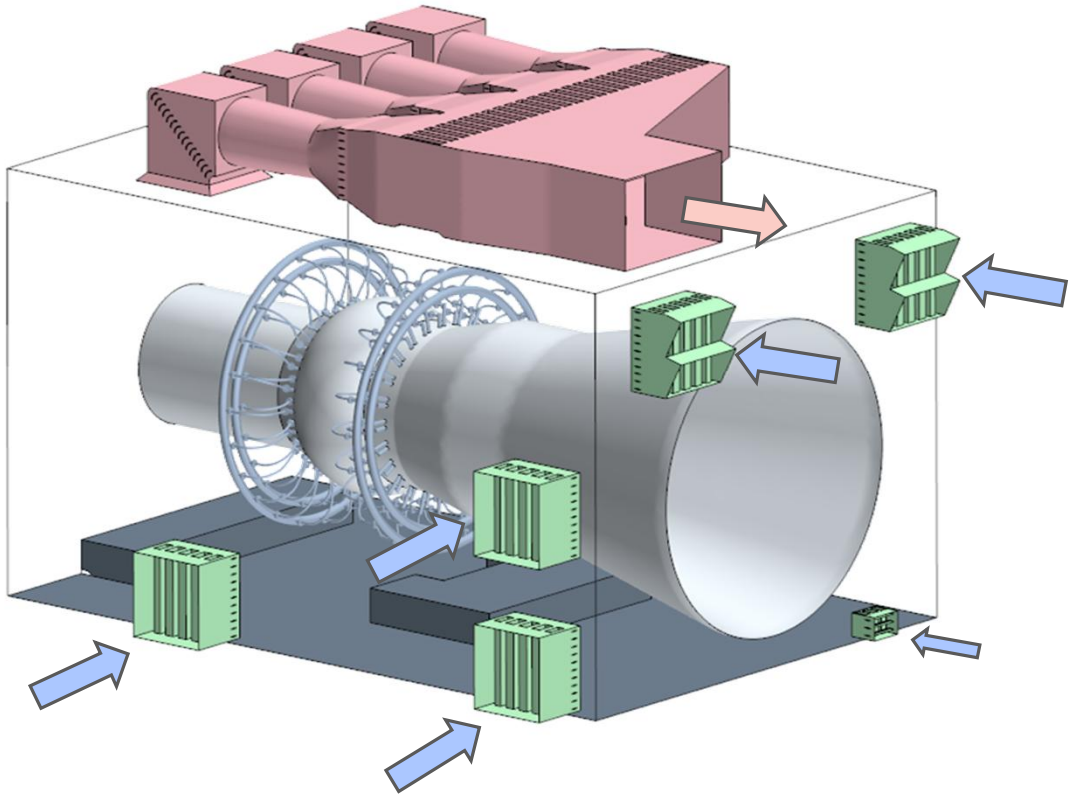
Model of GT 26 enclosure



Dimension Enclosure
12m x 12m x 12m

Air Flow
Min: 9 m^3/s
Max: 50 m^3/s

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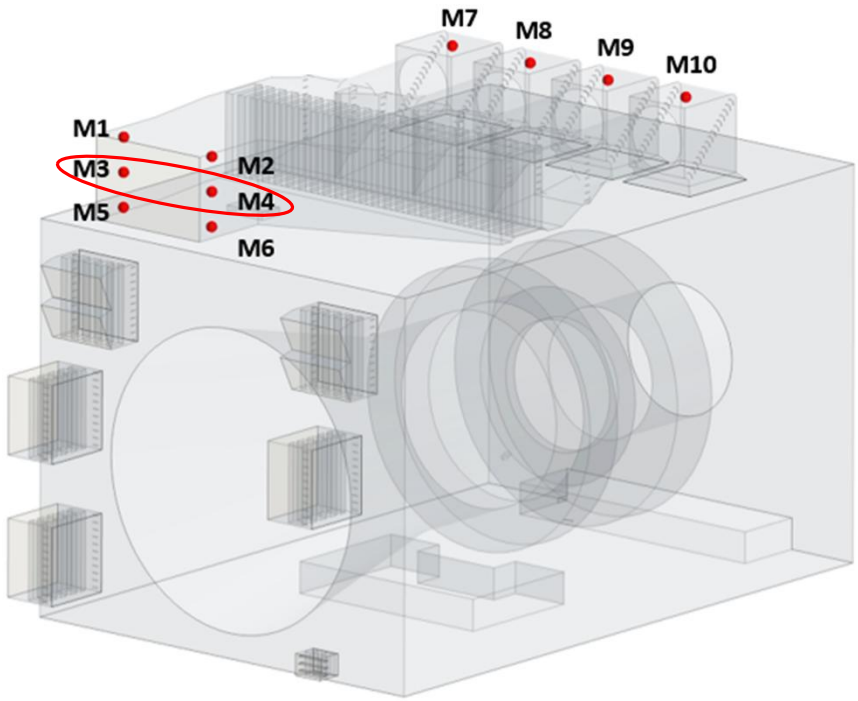
Gas detection points in GT ventilation outlet duct

Pos. M3,M4: Standard Position of gas detectors GT enclosures

Pos M1-M10: CFD Gas concentration readings



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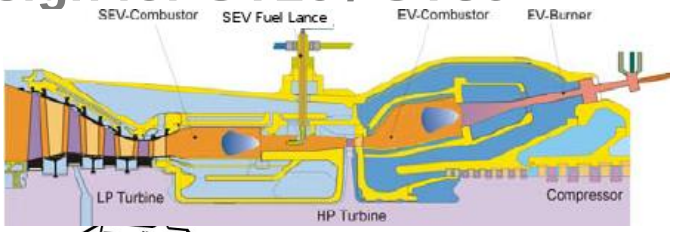
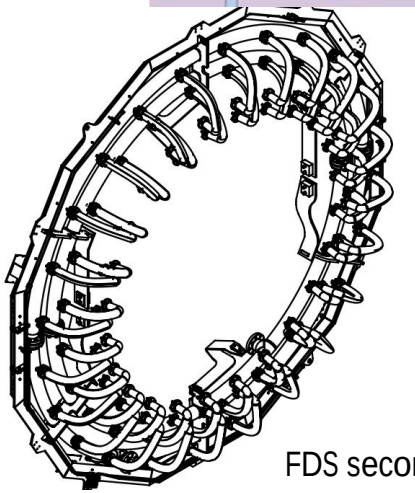
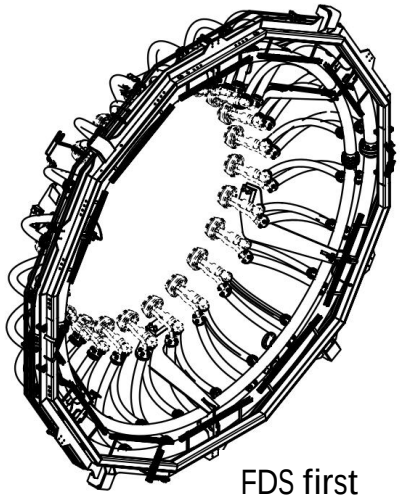
FDS design for GT26 / GT36

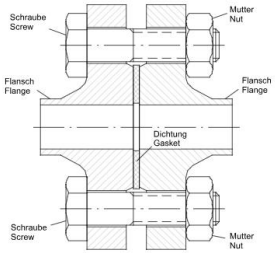




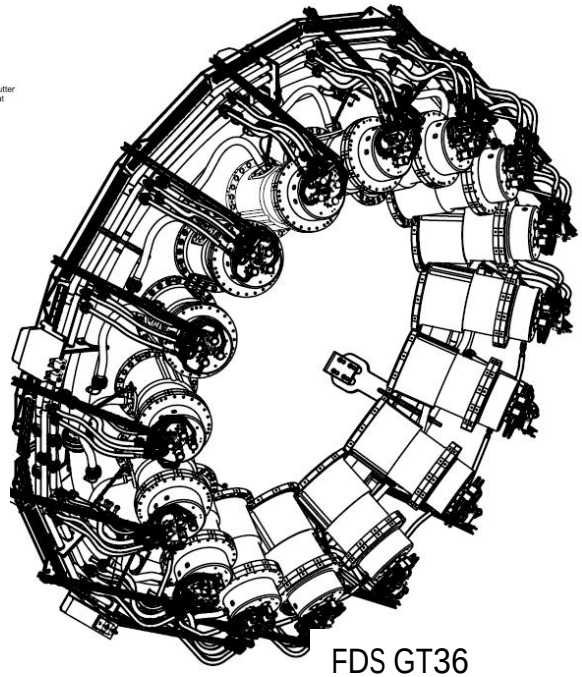
FDS second combuster GT26 ~48Flanges



FDS first combuster GT26 ~96Flanges



Used flanges
Raised face flange (RF)



FDS GT36 ~200Flanges

All flange connections are potential leakage points

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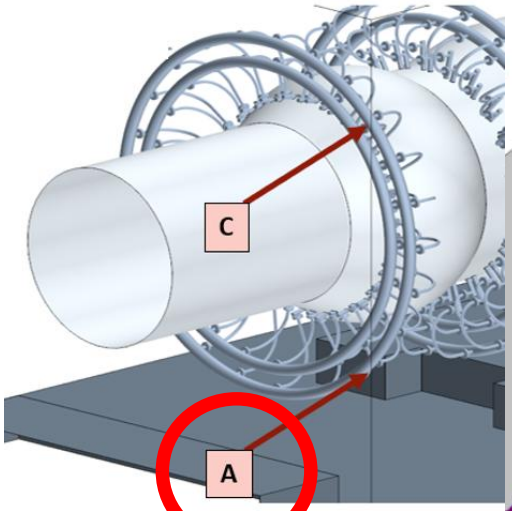
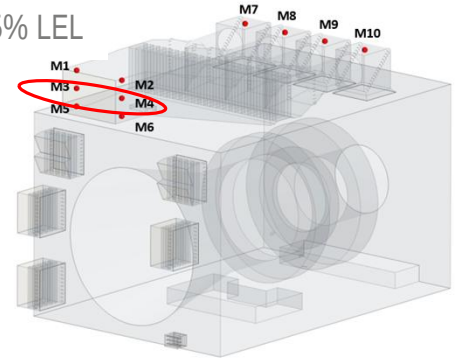
Hydrogen explosive Cloud on leakage point A



H2 Cloud size 100% LEL: ~41 m^3

Time until Alarm value was reached was 17s

Alarm value 5% LEL



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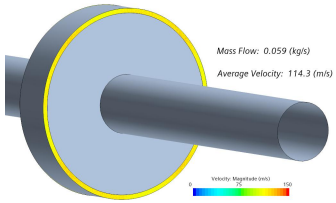
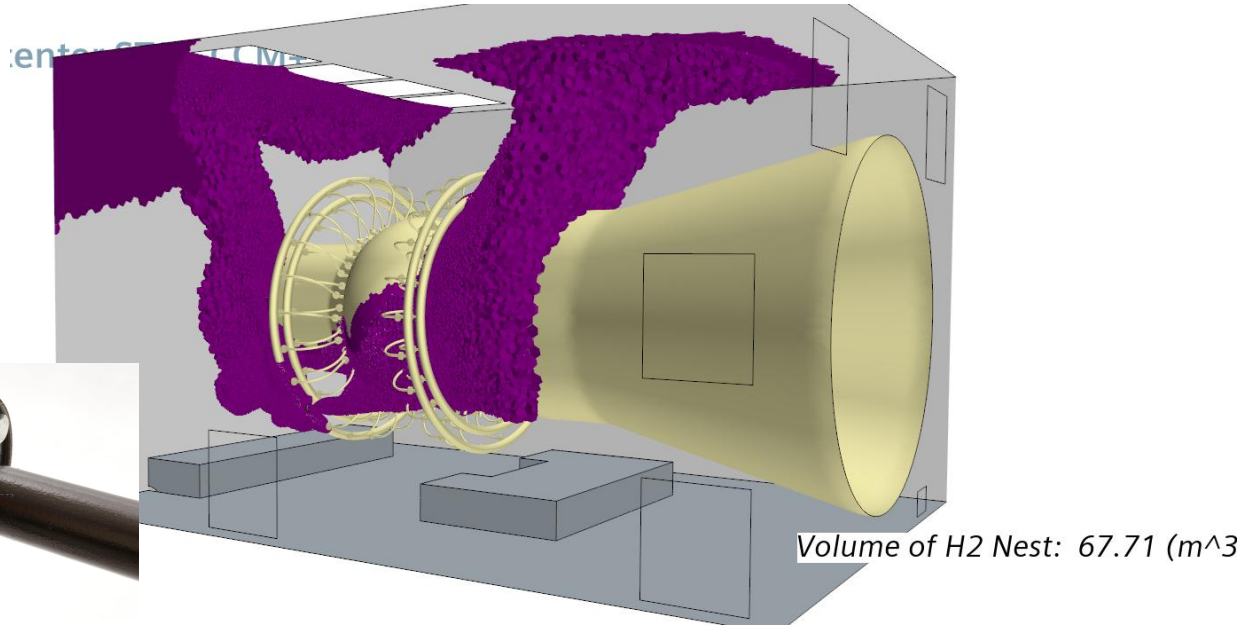
Iteration 1 – metallic cover (cuff) over flange

Boundary conditions:

- Hydrogen nest after 17 s
- Recirculating air: 9 m^3/s

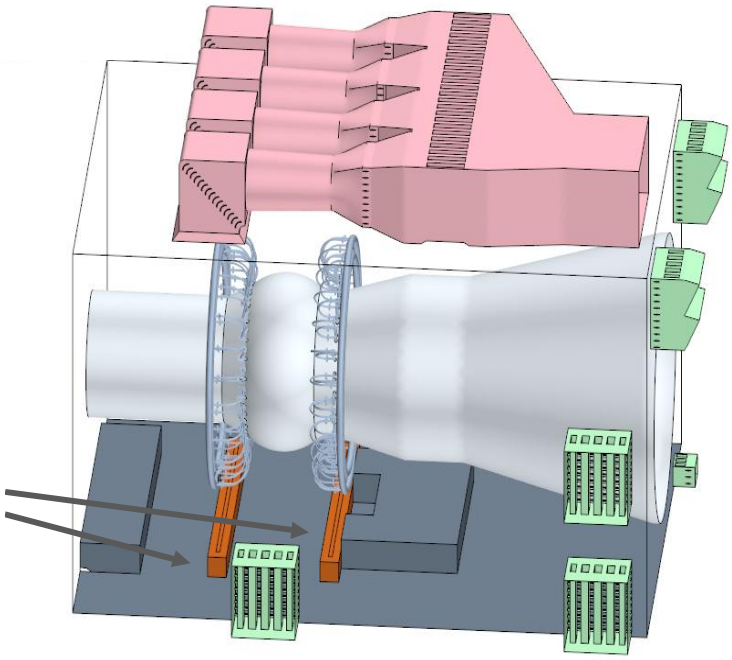




Result Negative

Metallic cover over flanges does not decrease the cloud size (the volume of gas is defined by crucial expansion)
The cloud size may even by increased.
The ventilation air flow was still not strong enough to blow out the H2 cloud.

Iteration 2 – ventilation air ducts below FDS



New Equipment

Recirculation ventilation:
Holes 5 cm diameter

Result Positive

Ventilation air ducts increase the air exactly at the location around the FDs, where leakage appears.

(leakage cloud will be diluted exactly at the location where it appears)

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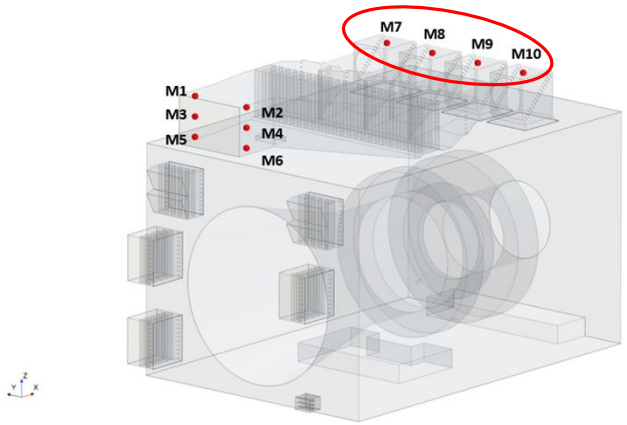
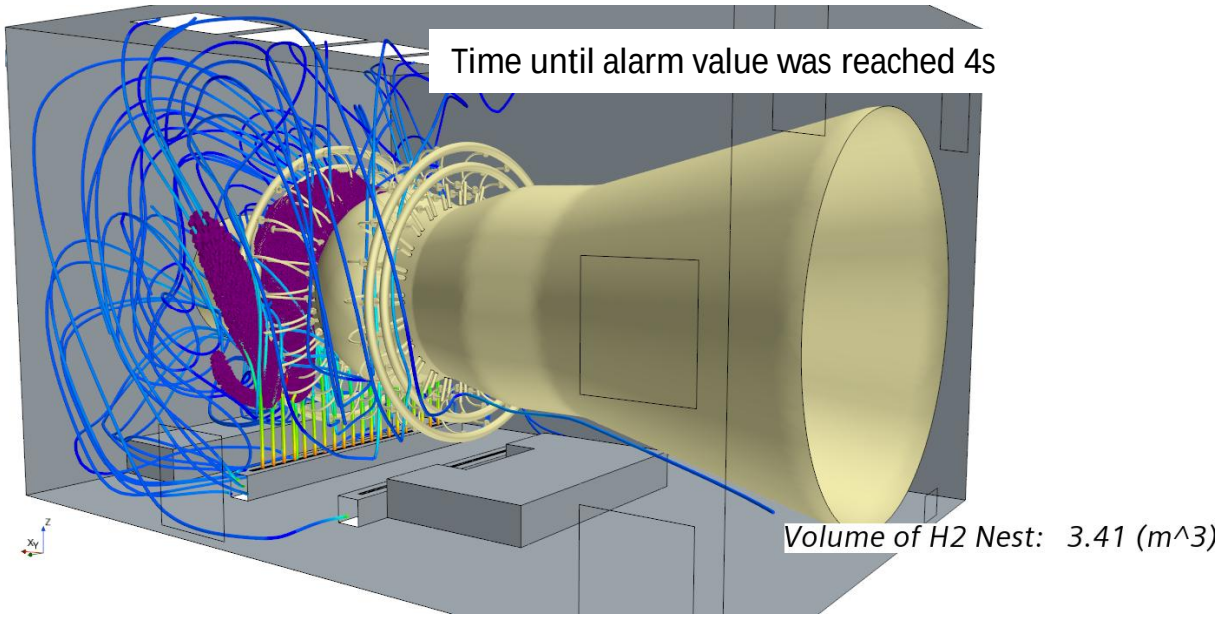
Iteration 3 – ventilation air ducts below FDS

Hydrogen nest after **4 s** (target: reduce gas detection reaction time to 4 s.)

- Recirculating air: 25 m^3/s, supply air: 9 m^3/s
- No cuff installed





Result Positive

Ventilation air ducts increase the air exactly at the location around the FDs, where leakage appears.

(leakage cloud will be diluted exactly at the location where it appears)

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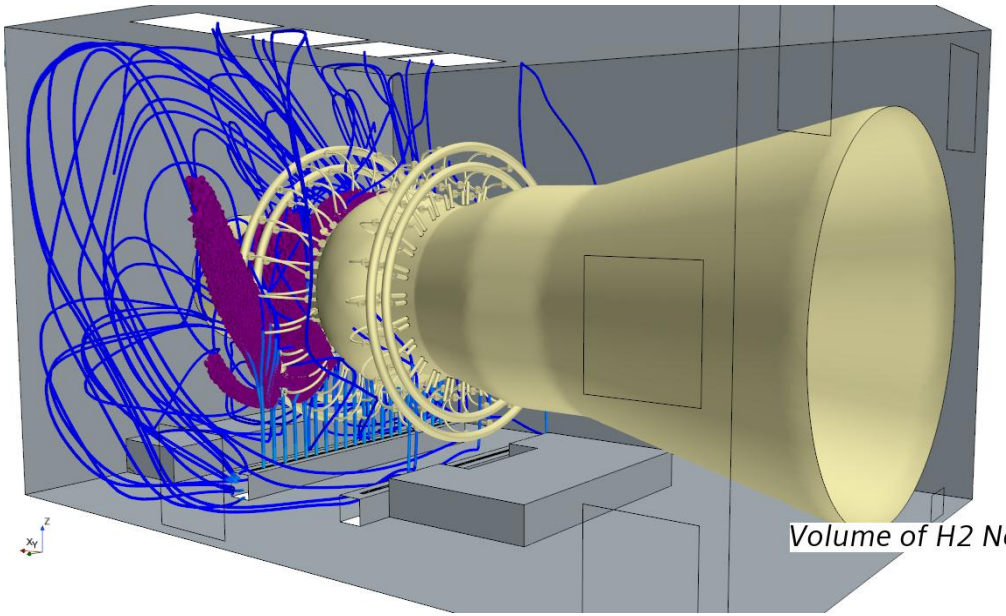
Iteration 4 – Increase ventilation air flow

Hydrogen nest after **4 s** (target: reduce gas detection reaction time to 4 s.)

- Recirculating air: 25 m^3/s, supply air: 20 m^3/s (increase main air ventilation from 9 m^3/s to 20 m^3/s)
- No cuff installed



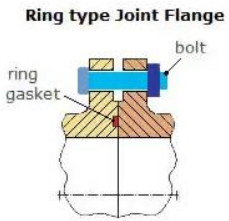
Result Neutral

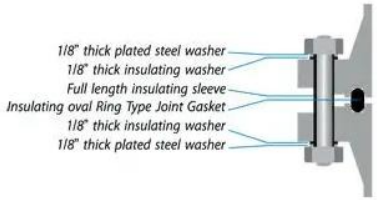
Small increased normal ventilation air flow does not have a considerable impact on leakage cloud size

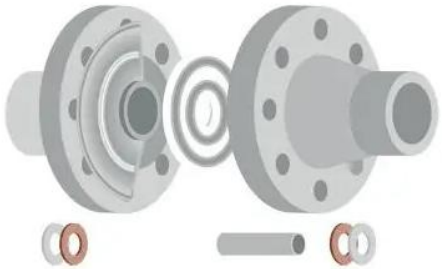
Possible Design Changes:

1. Reduce leakage in the worst case.

- To reduce the size of the leakage, a different flange system needs be used in the gas system.
  This new flange system should have a lower standard leakage rate.
- Which flange design will have the necessary low leakage rate has to be worked out in a separate process. This can be done as soon as the detail design for all H2 components is carried out.







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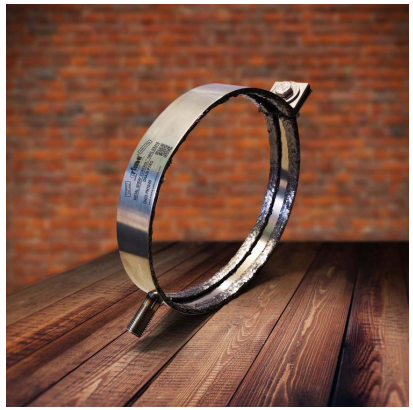
Possible Design Changes:

2. Reduce leakage time

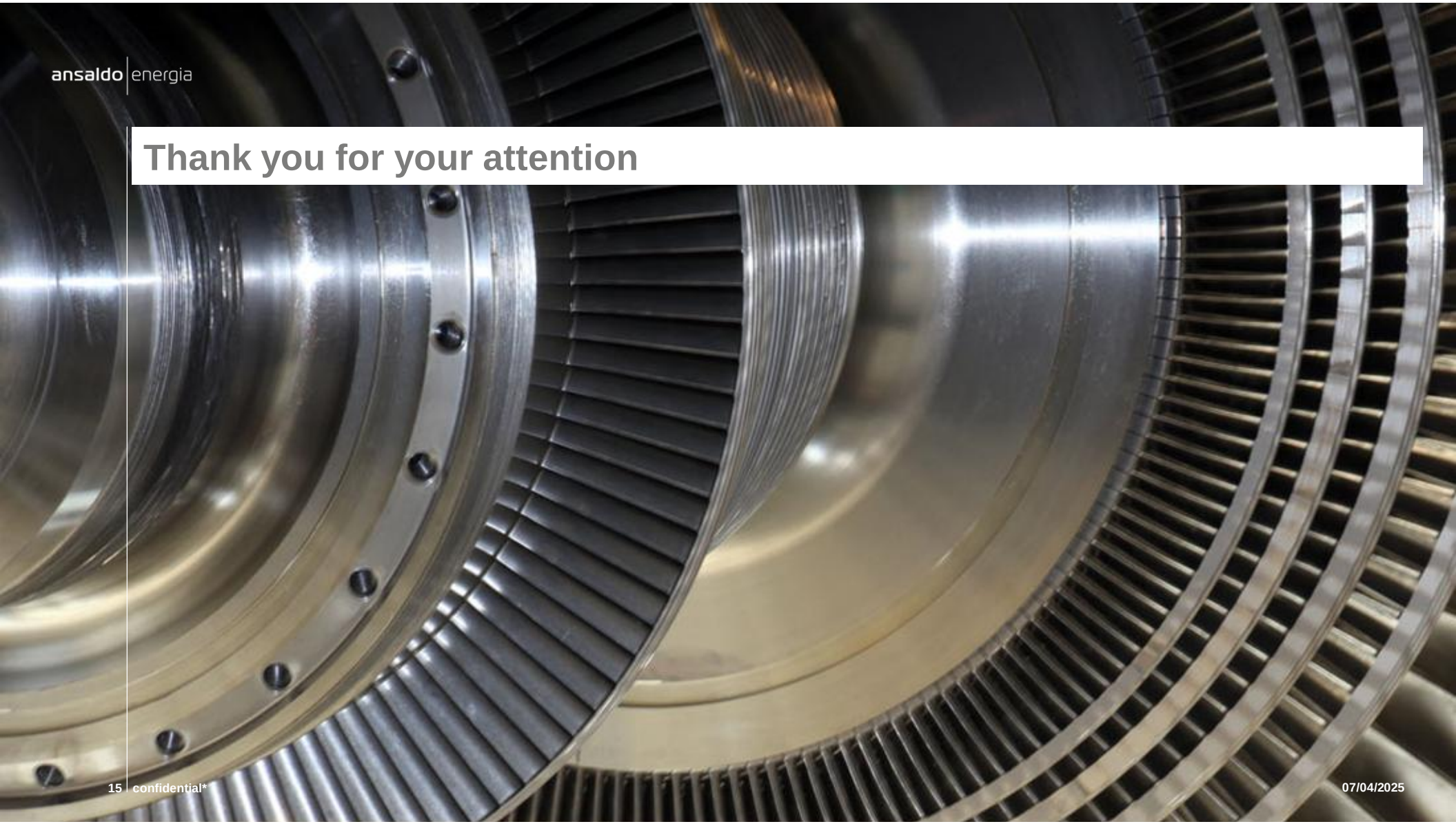
- To reduce the time between the leak occurring and the leak being detected, the gas sensors must be moved as close as possible to the possible leak positions. The sensors must also have a much faster response time.
- Improvement of air flow in the enclosure with additional Fans below the FDS

3. Extraction of leakage gas.

- An extraction system has been developed to extract liquid fuels, and we considered to adapt it to extract hydrogen leakages and transport them to the outside via a separate system.



As it is visible the way to operate the enclosure safely on H2 is not yet done, but there is a way to do it.



Thank you for your attention