

# Artificial Wind-Assisted Control of Hydrogen Gas Leaks for Improved Sensor Detection: A CFD Study

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## Summary:

This CFD study evaluates an artificial wind-assisted approach to actively control, detect, and localize hydrogen gas leak plumes. Detecting hydrogen leaks is challenging due to strong buoyancy and rapid multidirectional dispersion, which may cause leaked gas to bypass stationary sensors. The results show that moderate blower-generated air jets can steer hydrogen plumes over distances exceeding 15 m while maintaining gas concentrations within detectable ranges. Interaction between the airflow and surrounding surfaces promotes near-ground plume transport, mitigating buoyant rise and increasing sensor exposure time. The proposed approach enables more cost-effective sensor deployment and improves detection robustness and localization capability, particularly in scenarios involving multiple simultaneous leaks.

**Keywords:** CFD, gas leak detection, artificial wind, sensors, hydrogen

## Background, Motivation and Objective

Hydrogen leak detection is challenging due to the intrinsic high buoyancy and rapid diffusion of hydrogen, which lead to complex plume trajectories that may compromise safety at industrial facilities if undetected [1]. As a result, leaked gas can bypass conventional point sensors even when these are placed near expected leak locations. Current hydrogen safety systems rely mainly on passive detection, often requiring dense sensor deployment to compensate for uncertain plume paths. This increases system complexity and cost while still leaving detection gaps, particularly in open or semi-open environments [2]. Computational fluid dynamics (CFD) has been widely validated for predicting hydrogen dispersion and supporting safety-oriented design in industrial settings [3].

The objective of this work is to assess, using CFD simulations, an alternative strategy in which blower-generated artificial airflow is used to actively control hydrogen plume trajectories and guide leaked gas toward strategically positioned sensor arrays.

## Description of the New Method or System

The proposed system combines strategically positioned air blowers with downstream hydrogen gas sensors to actively manage dispersion following a leak. As illustrated in Fig. 1A, the artificial airflow intercepts the hydrogen plume shortly

after release and steers it toward a predefined detection zone, rather than relying solely on passive transport.

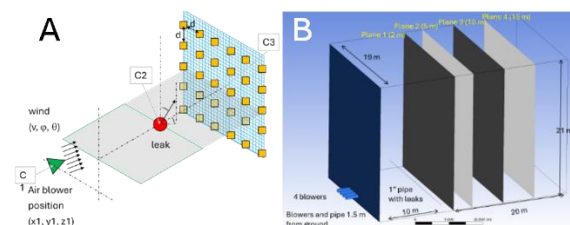


*Figure 1. A: artificial wind-assisted gas leak detection system. B: schematic of CFD model. Vertical planes are non-physical, only for viewing gas concentration contours.*

Moderate airflow velocities are intentionally targeted, as wind speeds on the order of 5–7 m/s are known to dominate hydrogen plume transport without excessive dilution [4]. The artificial wind-assisted concept is evaluated using CFD, exploiting the established capability of numerical models to capture combined momentum- and buoyancy-driven hydrogen dispersion. The analysis focuses on plume controllability, downstream concentration levels, and sensitivity to blower configuration and leak positioning, with particular attention to maintaining hydrogen concentrations within the detection range of commercially available sensors. By shifting leak detection from a passive to an actively managed process, the proposed approach enables wider

coverage, improved leak localization capability, and greater flexibility in sensor placement for complex industrial environments.

## Results

The CFD model geometry and the relative positions of the blowers and multiple hydrogen leak sources are shown in Fig. 1B. Downstream of the simulated leaking pipe, the airflow progressively attaches to nearby ground surfaces, promoting downward deflection of the hydrogen plume and sustained near-ground transport. This behavior, visualized in Fig. 2 (left column), is attributed to the Coanda effect, which has been widely reported for wall-jet and near-surface flows and is reliably captured in CFD simulations [5]. The resulting plume trajectory counteracts rapid vertical rise and increases exposure time for ground-mounted sensors.

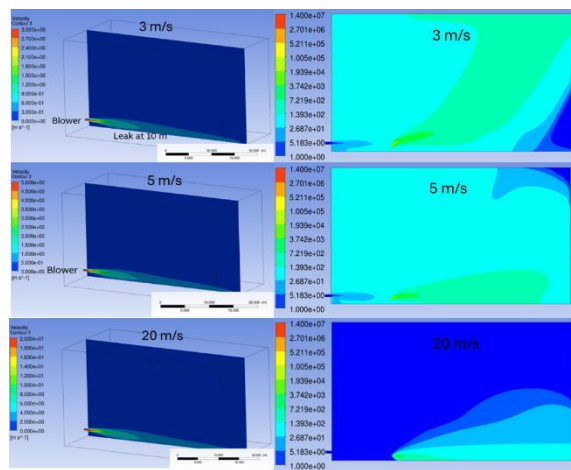


Figure 2. Left column: air stream grazes the ground surface downstream from the blower. Right column:  $H_2$  concentration distribution under air stream at different speeds. Gas leakage rate 0.4 kg/hr.

As shown in Fig. 2 (right column, top), at low air-jet velocities ( $\sim 3$  m/s) the induced airflow is insufficient to counteract buoyancy-driven plume rise, resulting in limited plume steering. Partial control emerges at approximately 5 m/s (Fig. 2, right column, middle), consistent with hydrogen dispersion behavior under moderate cross-flow conditions [4]. Gas concentration profiles extracted at downstream planes reveal a trade-off between plume confinement and dilution. While higher air-jet velocities ( $\sim 20$  m/s; Fig. 2, right column, bottom) further enhance plume control, they reduce hydrogen concentrations below 50 ppm, surpassing the lower detection limits of many commercial hydrogen sensors. Consequently, an air-jet velocity of  $\sim 7$  m/s provides the most favorable balance between controllability and detectability.

Subsequently, multi-leak scenarios distributed along the pipeline were simulated. Spatially distributed blowers enable simultaneous steering of

multiple plumes toward a common downstream detection region (Fig. 3), while preserving detectable hydrogen concentrations ( $>50$  ppm) at distances exceeding 15 m from the leak sources. These results demonstrate the robustness of the proposed approach for diverse industrial layouts.

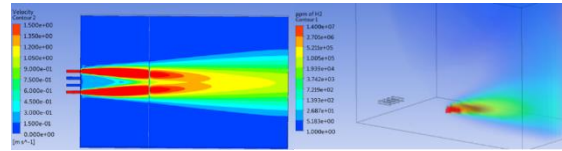


Figure 3. Left: top view of air velocity contours; right: distribution of concentration of  $H_2$  emanating from all leaks.

## Conclusion

The CFD results demonstrate that moderate artificial airflow can effectively control buoyant hydrogen gas leak plumes across a broad plane, mitigate rapid vertical rise through surface-attachment effects, and preserve gas concentrations within sensor detection limits across longer distances from the leak source. By shifting hydrogen leak detection from a passive to an actively managed process, the proposed artificial-wind-assisted approach enhances sensing coverage, localization robustness, and flexibility in sensor placement for complex industrial environments. Using CFD modelling, it was possible to optimize the air velocity and blower positioning required to adequately control gas plumes over a broad leakage area, as well as to determine how far downstream the target gas could still be detected. The promising results from these studies are planned to be demonstrated throughout future field testing.

## References

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