



Enabling the  
decarbonisation of  
Australia's energy  
networks

## Future Fuels CRC RP3.2-12: Two Page Summary of Research

### Addressing hydrogen blending issues (Part B: demixing potential)

With the progression of studies and pilot projects involving hydrogen and natural gas blending, there have been open queries as to the potential stratification of hydrogen and natural gas mixtures – what mechanisms may lead to stratification, and is this potential significant and likely enough to require active management through the design and operation of blended gas systems.

To better understand a number of key issues arising from the blending of hydrogen into natural gas networks, Future Fuels CRC research project RP3.2-12 – 'Addressing hydrogen blending issues: gas mixing, demixing and hydrogen analysis' was proposed. The research of the project has been carried out in two parts: Part A: hydrogen/natural gas mixing and hydrogen analysis; and Part B: hydrogen/natural gas demixing potential. The goal of Part A is to optimise the technology for effective mixing and monitoring of hydrogen blends concentrations. That of Part B is to identify the envelop of conditions giving rise to stratification and clarify the severity of the stratification process.

This research summary provides an overview of Part B. The study included an initial literature review to identify prior research and potential mechanisms that may lead to stratification, followed by numerical simulations to assess specific cases applicable to hydrogen/natural gas blends in pipeline systems.

The literature review focused on various key topics, including:

- 1) Prior experiments on gas releases in closed spaces relevant to gas demixing/stratification.
- 2) Prior experiments on gas diffusion relevant to gas demixing/stratification.
- 3) Thermodynamics of mixing ideal gases.
- 4) Gravitational stratification.
- 5) Thermal diffusion.
- 6) Mass and thermal diffusivity of hydrogen/methane mixtures.

Main observations from the literature review include:

- 1) Density difference between gas components cannot sustain stratification while on the contrary stratified gases tend to mix and achieve a uniform concentration.
- 2) Demixing due to density difference does exist but the effect is very limited.
- 3) Thermal diffusion due to temperature gradient can lead to demixing, with a concentration gradient developing until the separating effect of thermal diffusion is balanced by the mixing effect of mass diffusion.

In the context of demixing/stratification in hydrogen/natural gas mixtures, the literature review suggests that the mechanism of relevance is the potential for thermal stratification, where a temperature gradient is applied across a static system thereby inducing component separation due to the thermal diffusion along the temperature gradient.

Following outcomes from the literature review, numerical simulations were completed to study the demixing/stratification potential of hydrogen/methane mixtures under joint action of buoyancy, mass diffusion and

thermal diffusion. A total of 540 cases were simulated for the demixing potential of blended gases, and at the same time, a total of 72 cases were simulated for the mixing potential of initially separated gases. The affecting parameters considered include the hydrogen fraction, pipe diameter, pipe length, pressure, and temperature gradient.

Key findings from the numerical simulations include:

- 1) Thermal diffusion due to temperature gradient can lead to demixing of hydrogen/methane mixtures. A concentration gradient will develop until the separating effect of thermal diffusion is balanced by the mixing effect of mass diffusion.
- 2) Higher pressure or larger temperature difference will lead to more component separation across the temperature gradient.
- 3) A hydrogen/methane mixture with 50% hydrogen (mole fraction) has the greatest demixing potential in the cases simulated. The demixing potential of a hydrogen/methane mixture with 90% hydrogen is significantly lower than that of a hydrogen/methane mixture with 10% hydrogen.
- 4) Increase in pressure or increase in the distance associated with the temperature difference will cause significant increase in time required for the demixing to reach a steady state.
- 5) Hydrogen/methane mixtures do not present a very strong component separation tendency. A temperature difference of 50 °C can cause a maximum hydrogen mole fraction difference of about 4% (e.g., in a 50%hydrogen/50%methane mixture, a 50 °C temperature difference can lead to a composition of 52% hydrogen at the high temperature end and 48% hydrogen at the low temperature end).
- 6) Density difference between gas components is not able to cause noticeable component separation. On the contrary, a stratified mixture would naturally mix to become more homogeneous due to mass diffusion disregarding the density difference.
- 7) Increase in pressure or increase in the distance associated with the stratified gases will cause significant increase in the time required for the gases to fully mix.

The literature review and numerical simulations have determined that density difference between gas components is not able to cause noticeable component separation. On the contrary, a stratified mixture would naturally mix to become more homogeneous due to mass diffusion. The only driving force which could cause noticeable component separation is thermal diffusion. However, numerical simulations show that hydrogen/methane mixtures do not present a very strong component separation tendency under a relatively high temperature difference. Also, thermal diffusion is a slow process, especially at elevated pressures, which implies that the gas mixture can readily return to a homogeneous state during this process if disturbances like temperature fluctuations or alterations in flow are introduced within the pipeline.

Overall, stratification/demixing due to density or temperature difference in a blended hydrogen/natural gas system is limited. No additional controls are required to prevent stratification/demixing in natural gas/hydrogen pipelines.

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