Engineering Development of Rhino HySafe Vertex Explosion Relief Panels

The Rhino Engineering Team worked hard for three years to successfully develop our low-inertia, rapid-acting explosion relief vent for the hydrogen economy.

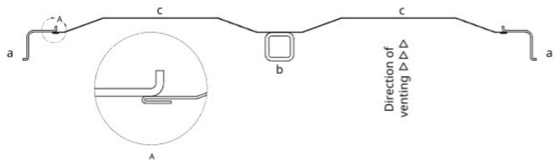
Hydrogen is one of several flammable gases that can shift from a slow burn known as deflagration to a fast, explosive burn known as detonation under certain conditions. This increases the explosion risk in some uses.

To prevent hydrogen explosions, effective venting is crucial while still in the early deflagration stage. Proper and adequate venting at this stage can significantly reduce the risk of a dangerous transition to detonation and significantly lower the chance of highly damaging hydrogen detonations.

Development Process

Developing our Vertex relief panel began with our experienced team reviewing relevant codes and standards for hydrogen facilities, such as fuelling points, hydrogen production units, and their related infrastructure. We reviewed these extensively to achieve specific outcomes, such as reducing the mass inertia of panels while comfortably meeting the low inertia threshold.

Throughout the process, consideration was always given to manufacturing processes, material selection, ease of handling during manufacture and installation, and the vent panels' durability whilst in service. Along with a more detailed analysis, we developed the critical features of the vent panel design after several early iterations.



Initial Testing

After 3 months in the engineering design process, we had established reasonable confidence in the panel design. We did this using sensitivity simulations using the plane strain explicit dynamics model.

A test rig was prepared to allow a test panel to be progressively loaded with sandbag ballast. Static displacements were measured during loading, and the final total load was recorded at the

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moment of panel activation. This was to measure the static activation pressure, a vital variable required for vent panel sizing codes.

In doing so, we observed that these straightforward, low-cost physical tests were instrumental in helping to anchor nonlinear analysis, especially when complicating factors such as contact interactions and strong geometric nonlinearity are in play.

We then carried out several tests using the dynamic pendulum test apparatus we had designed and fabricated. High-speed video footage was also captured for each test.

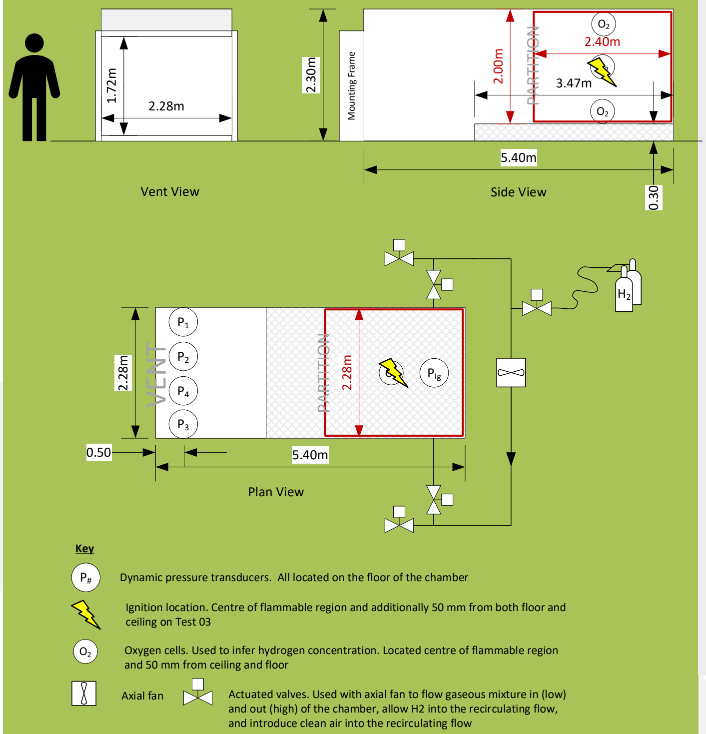
After completing these tests, further analytical work was carried out before the full-scale explosion testing programme.

One objective achieved was to create a fully defined threshold in the overpressure-impulse space so that specifiers could fully appreciate panel activation conditions.

Full-Scale Explosion Testing

Full-scale explosion tests were carried out in 2022 at the DNV Spadeadam test site in Cumbria using their 26m³ chamber.

Eight production tests were carried out, with peak overpressures immediately upstream of the panels, ranging from 21 mbarg to 850 mbarg.



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Data was measured in many different ways to ensure reliability and accuracy. This included capturing video from PHANTOM high-speed cameras placed at two vantage points, operating at approximately 3,000 frames per second, depending on ambient conditions.

The extensive testing allowed us to see what elements were successful and what needed more work with regard to reliability, speed of activation, accuracy of the ABAQUS/Explicit analysis/design model, prevention of debris and missile formation and more.

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