Outline summary of design & testing of Rhino HySafe UFER explosion relief panel system

Introduction & background

Venting is an essential tool in the mitigation of explosion hazards throughout industry, and is fundamental in limiting the severity of dust, gas and hybrid[1] explosions in many applications. Explosion vents seek to provide a passive, rapidly acting and safe path through which blast overpressure, flame and combustion products may be directed before damaging levels of overpressure can accumulate within a piece of equipment or a building.

Reliable, predictable and rapid operation of explosion vents is of paramount importance, as reflected in applicable international standards used in the design of explosion relief vents, such as NFPA 68, BS EN 14491 and VDI 3673 Sheet 1. FM Global Property Loss Prevention Data Sheets 1-44 and 7-76 also contain valuable guidance, and further emphasise the importance of ensuring suitably low opening pressure and low vent panel inertia.

The explosion hazard mitigation needs of emerging sectors, such as the expanding use of hydrogen as an energy carrier, are of growing importance. The new international standard for gaseous hydrogen fueling stations, ISO 19880-1, stipulates the need for careful consideration of suitable means of venting hydrogen deflagrations within enclosures.

With these established and emerging needs in mind, Rhino HySafe have embarked upon a significant design and testing programme to develop the new UFER explosion relief panel system.

[1] "Hybrid" is a specific technical term referring to explosions arising from gas/dust mixtures. These can occur in certain industries which handle organic materials that produce both flammable dusts, as well as gases from decomposition.

Design of UFER explosion relief panel

Stimulated by the particular needs of hydrogen deflagration venting, Rhino HySafe combined long experience in the design and fabrication of building components for demanding fire and blast applications with detailed, explicit-dynamics simulation techniques to create a new, rapid-opening, low-inertia relief panel – UFER.

The UFER panel system relies on a simple, highly reliable structural principal to achieve the required balance between ease of panel opening, with a low static pressure (P_{stat}), and repeatable operation under a wide range of blast loading conditions (dP/dt, applied overpressure and impulse).

The UFER panel release mechanism has been designed to avoid mechanical fixings or other elements which have the potential to increase complexity or uncertainty. A large number of explicit-dynamics simulations were performed to substantiate the fundamental configuration of the panel components, whilst a range of static and dynamic physical tests were performed in parallel to underpin the numerical modelling. Close correspondence between design calculations and initial mechanical testing paved the way for full scale explosion testing at the renowned DNV Spadeadam hazards testing facility in the UK.

Full scale explosion testing of UFER panel

In order to provide robust confirmation of the panel system's performance under demanding deflagration venting conditions, full scale explosion tests were performed, using hydrogen as the fuel, across a range of flammable cloud reactivities. These tests were configured to ensure that the entire UFER panel system was subjected to conditions of peak overpressure, rate of pressure rise (dP/dt) and combustion product outflow substantially in excess of intended design conditions. Care was taken to measure initial panel opening time and time to fully open configuration under rates of pressure rise differing by at least an order of magnitude. All components of the overall system were included in the tests; seals, flashings, fixings and the supporting structural cassette.

The full-scale tests demonstrated prompt panel opening, well ahead of flame-front arrival, and swift transition to a fully opened configuration, allowing unencumbered outflow of the flame-front and combustion products. Furthermore, complete retention of the panel elements was demonstrated, substantiating the design of the structural cassette and associated fixings.

The substantial volume of test data captured by DNV during the tests, including high speed video, was subsequently used to validate the previous design calculations.

Full definition of UFER panel performance envelope

Rhino HySafe remain determined to maximise the range of application of the UFER panel system, and crucially, to provide design engineers with maximum insight into the performance characteristics of the panel in providing explosion relief across a wide range of hazard conditions. To that end, a fully defined performance envelope has been prepared, in pressure-impulse space, so that designers and specifiers have a complete view of the UFER panel opening criteria. This performance envelope has been validated by reference to static, pendulum impact testing and full-scale explosion testing, under the severe conditions associated with hydrogen deflagration.

As shown below, the demonstrated performance envelope straddles the static, impulsive and dynamic range, illustrating the value of P_{stat} at 20 mbarg (0.3 psig), and minimum opening impulse of 325 mbarg·ms (4.7 psi·ms). These properties, combined with a panel specific mass of < 6 kg/m^2 ensure a rapid, low-inertia response following panel opening.
This iso-opening curve provides rapid insight into the UFER panel performance, independent of the explosion loading conditions of concern to the designer.