Explosion safety for gas engines

Any unburned gas/air mix in the exhaust system of a gas engine can be highly explosive, so that adequate protection is a must. The following article shows you how such protection can be achieved in a way that is both, cost-effective and sustainable.

(GAS) EXPLOSIONS – A FEW THINGS YOU SHOULD KNOW

In order to explode, gas needs certain “ingredients” – combustible gas and oxygen – at a specific ratio, which must then be combined with a source of ignition. The resulting mixture of combustible gas and air is explosive if it occurs within certain upper and lower explosion limits (Figure 1).

There also needs to be an effective source of ignition: “An effective source of ignition is one where the relevant explosive atmosphere can cause an explosion.” [TRBS 2152 Part 3, “Hazardous explosive atmosphere – avoiding the ignition of a hazardous explosive atmosphere”, page 2].

Gas engines are often unsafe, as it is often impossible to avoid an explosive atmosphere. In particular, there is no way to prevent the appearance of an effective source of ignition. In particular, hot surfaces on the exhaust system, caused by high combustion temperatures, are simply unavoidable. This means that designers need to take specific precautions to reduce the impact of an explosion to an acceptable level.

Fuels such as LNG (methane), biogas and landfill gas have certain properties that need to be taken into account during operation. There are two main reasons which may lead to undesirable emissions in the exhaust system.  
1. Methane leakage through valve overlap: In a four-stroke engine both the inlet and the outlet valves are briefly open between the first and the fourth stroke. The air/gas mixture then serves to rinse the cylinder. As the outlet valve is also open, part of the unburned mixture gets into the exhaust system.

2. Incomplete combustion: Sub-optimal operating conditions cause the flame in the combustion chamber to go out too early, so that the unburned mixture passes into the exhaust system. Such conditions may be a partial load, a high engine speed, a low temperature in the engine or a partially low gas concentration. Together with the thermal properties of gas, such conditions then cause the flame to be extinguished prematurely. One operating state, in particular, that can favour the occurrence of an explosive atmosphere is operation under a partial load, as it can involve extremely high temperatures.

CRITICAL SITUATIONS: START-UP AND RUNNING-IN PROCESSES

Start up and running-in processes involve higher volumes of an unburned mixture passing into the exhaust system and leading to a worst-case scenario. Plant designers therefore often add vent areas on the exhaust system in their plans. In many cases, however, these are only implemented at the beginning of the exhaust pipe, to protect the downstream catalyst. Yet, depending on the length of the pipe and the number of installations, it would be important to increase the number of vent areas. This is necessary in order to reduce the spreading of any pressure or explosion after the first relief opening or indeed to provide direct relief for any ignition that might occur in the latter part of the exhaust pipe. This prevents the development of critical overpressure in the exhaust pipe and in any of the installations.

Figure 1: An explosive atmosphere: lower and upper explosion limit

lower explosion limit

ideal/stoichiometric mix

upper explosion limit

mix not rich enough

explosive atmosphere

mix too rich
The wider the diameter of the exhaust pipe, the more important it is to protect the system through explosion venting. Due to the large dimensions, even low pressure can release a substantial amount of force which then impacts the various components, causing deformation, damage or even rupture in the exhaust pipe. This is a major hazard for both humans and machinery. In each case system planners should therefore obtain advice from an explosion safety professional who will assess each constellation separately.

DECISIVE FACTORS IN EXPLOSION SAFETY

Two factors that should define whether and to what extent the exhaust gas system in a gas engine requires protection is the stability of the built-in elements, on the one hand and any process-induced overpressures on the other. All parts are in fact relevant in this connection, including installations such as catalysts and exhaust silencers. Other factors that also affect the development and vehemence of an explosion are the length of the exhaust system and any possible curvatures. In the literature on the subject gas explosions in pipelines are classified as especially dangerous. This is because the flames are accelerated, leading to so-called deflagration which then causes a far more violent detonation, often peaking at up to 30 bars. In gas engines under normal operation the pressure can be expected to be somewhat lower, as only part of the exhaust tract is usually filled with an explosive, unburned mixture. Moreover, the gas/air mixture is not stochiometric, but usually thin, with a lambda (λ, air-fuel ratio, AFR) above 1.

CONSTRUCTIONAL EXPLOSION SAFETY SYSTEMS FOR GAS ENGINES

Conventional venting through the use of explosion vents outdoors

If the exhaust system of a gas engine is at least partly situated outdoors, it is usually possible to install explosion vents for pressure relief purposes. If an explosion occurs, the resulting overpressure and flames are discharged to the outside via a pressure-relief opening. This provides reliable protection of the exhaust system against the harmful impact of an explosion.

Under normal operation an explosion vent is always subject to specific requirements, as it needs to cope with very high temperatures around 540°C as well as pulsations and overpressures. The response pressure of the explosion vent is specified at a sufficiently high level to counteract any possible process overpressure and to prevent any turbulences which might occur if, in the course of an explosion, the vent opens too early (Figure 2).

Explosion venting within buildings

In most cases the gas engine itself and also large parts of the exhaust track are located inside a building. The spreading of flames and pressure therefore makes it impossible to use explosion vents to protect the environ-
ment around the gas engine sufficiently well. One option might be to add vent ducts which take the explosion outside the building, into the open air. However, the maximum length of such vent ducts is limited. The longer the distance of the explosion, the higher the pressure coming from the centre of the explosion. Also, this method prevents any optimum use of space, as the outdoor area, too, needs to have safety zones for pressure relief purposes. Installing vent ducts is often rather expensive and space-consuming.

Flameless venting

The most efficient and cost-effective solution is flameless venting, where the pressure can be safely relieved within an enclosed operating space. This is because the flames and the pressure cannot reach the environment (Figure 3).

The inventors of flameless venting – the German explosion safety professionals at REMBE – were the first to develop a flameless venting product for gas engines: The Q-Rohr G for gas engines on land and the Q-Rohr DFE for gas-powered marine engines.

The Q-Rohr has been on the market since 1988. Until a few years ago it was mainly used for dust applications. Due to numerous developments, including a gradual turnaround in energy use, both on land and on waterways, it has become increasingly important to provide suitable protection for gas engines.

Developed initially for gas powered marine engines, the Q-Rohr DFE was very quickly certified and used as the Q-Rohr G for gas engines on land. It has a large number of certificates for maritime use provided by the Lloyds Register, DNV GL, Bureau Veritas and ABS and also for land-based use from ATEX (Figure 4).

The special mesh fabric used in REMBE’s Q-Rohr G and DFE efficiently cools down the flames of an explosion and reduces any emerging pressures to a non-hazardous minimum.

Operators particularly value the speed with which they can restart a system after an explosion event, the very high level of system availability and the security of the power supply. Once installed and working under normal conditions, such an explosion vent delivers absolute tightness and reliability for many years.

The manufacturers mention the following benefits, in particular:

1. The explosion does not emerge, all parts of the engine and the exhaust tract remain intact, and operation can be resumed extremely quickly, as soon as the explosion vent has been replaced. The Q-Rohr G can be reused for up to 3 explosion events.
2. The forces impacting the pipeline are 50% lower compared with conventional relief provided via an explosion vent or vent duct.
3. Channel relief makes it unnecessary to provide outdoor safety areas.
4. Pressure relief directly within the building requires a relatively small safety area.
5. Leak-Tightness is 100% during normal operation.
6. Demonstrably less sound is emitted by the engine into the environment compared with vent ducts.
7. If an explosion occurs, a signal is sent to the engine controls, so that system operation can be reduced to a safe level.

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