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Considerations for hazardous area classification of modular hydrogen facilities

Hydrogen production is rising in popularity due to an increasing demand for clean energies and fuel alternatives. Hydrogen electrolysis is one method of hydrogen production that is both energy and space efficient. Hydrogen electrolyser components can be conveniently packaged into road transportable modules and placed close to renewable energy sources which makes them one of the greenest and most effective ways to produce hydrogen. However, such modular systems must be carefully designed to mitigate the hazards associated with hydrogen production. This is especially true for unmanned applications where such hydrogen production modules may be placed in close proximity to public facilities. In such cases, explosion safety becomes a prime consideration.

Hydrogen is a highly volatile and explosive gas that is much lighter than air. Hydrogen is a very small molecule with a molecular weight of 1.08 which makes it very prone to leakage. It also has a very low ignition energy threshold that is one tenth of the energy ignition threshold of gasoline-air mixtures. It has a wide flammability range between 4-74% (LFL) concentration in air and 4-94% (LFL) in oxygen at atmospheric pressures.

An electrolyser produces hydrogen through a petrochemical process called electrolysis which takes place within the cell stacks. The electrolyser consists of an anodic catalyst, a cathodic catalyst, and a membrane. Electricity is applied to the anode and cathode across the proton exchange membrane (PEM) and causes the water (H2O) to split into its component molecules, hydrogen (H2) and oxygen (O2). Hydrogen ions are attracted to the cathodic catalyst, while the oxygen ions are attracted to the anodic catalyst. A hydrogen production module may incorporate multiple electrolyser units as well as other system components including a power supply, water tank, filter, separator, pumps, vents, dryer, compression, storage cylinders, and other components. Many of the process components will operate at high pressures and incorporate multiple connections that may be prone to leaks. Another challenge is that many of the components may not be hazardous location certified. Such applications can be very challenging from an explosion safety perspective. We need to be able to define, monitor and control the explosion hazard and employ equipment explosion protection methods that are suitable for the application.

Many hydrogen electrolyser module applications will incorporate both non-hazardous and hazardous location rated equipment. Non-hazardous rated equipment must be isolated from hydrogen production equipment which usually warrants a classification design. One strategy is to design a module such that non-hazardous rated equipment is physically segregated from areas where there could be a hydrogen explosion hazard. This can be done using a purge scheme or by separating hazardous from non-hazardous areas using a vapour barrier.

A purge scheme involves slightly pressurising the non-hazardous area with fresh air to ensure that no flammable gases from the hazardous area can enter or migrate to the non-hazardous area. This ensures that hydrogen does not leak into the non-hazardous area where equipment can present an ignition hazard. Room purge applications can be quite complex when designed in accordance with IEC 60079-13 and NFPA 496 standards. The requirements for gas detection and equipment interlocks are described in these documents.

A vapour tight barrier can also serve to segregate a hazardous area from a non-hazardous area. A vapour tight barrier between two locations will prevent the migration of gasses between the two areas. A vapour tight barrier can be any material or construction methods that meets the criteria for a building "air barrier". Local

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building codes and standards incorporate specifications for an air barrier system and the same specifications will work when designing a vapour tight barrier for classification purposes. Many building materials include steel panels, concrete or sandwich construction insulated walls will meet this specification. All penetrations through the vapour tight barrier must maintain the integrity of the vapour barrier to be effective.

Another approach to installing non-hazardous rated equipment in classified areas is to interlock the equipment with gas detection. A flammable release will be detected by the gas detection system which will then start high-rate ventilation to disperse the release and shutdown the equipment to prevent the equipment from becoming an ignition source. The application of gas detection for equipment protection requires careful consideration. Local installation codes and regulations may not permit this option depending on the circumstances and the jurisdiction. The placement, the technology and the number of gas detectors required for total coverage must also be considered. The gas detectors specified must use a catalytic bead technology as infrared detection gas sensors cannot detect hydrogen. Gas detectors must also be monitored, maintained and periodically calibrated. A poorly maintained gas detector can become an explosion hazard by providing a false sense of security. A gas detector must function as the manufacturer intended for this option to be viable.

The best way to mitigate a hydrogen explosion hazard is by proper ventilation. A good ventilation design will ensure that any releases that may occur in normal operation will be rapidly dispersed by air movement and displacement. In unconfined open air, where good ventilation is almost always present, a small hydrogen leak will rapidly dissipate in an upward direction to below its lower flammable limit. This is primarily due to its low molecular weight when compared to air.

Grade of release	Effectiveness of ventilation						
	High Dilution			Medium Dilution			Low Dilution
	Availability of ventilation						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	Non-hazardous (Zone 0 NE)[a]	Zone 2 (Zone 0 NE)[a]	Zone 1 (Zone 0 NE)[a]	Zone 0	Zone 0 + Zone 2[c]	Zone 0 + Zone 1	Zone 0
Primary	Non-hazardous (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or Zone 0[c]
Secondary[b]	Non-hazardous (Zone 2 NE)[a]	Non-hazardous (Zone 2 NE)[a]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zone 0[d]

Table D.1 - Zones for grade of release and effectiveness of ventilation

Where ventilation for explosion protection becomes challenging is in enclosed and semi enclosed applications. Because of its very light molecular weight, hydrogen will collect in the upper areas of confined spaces. A very small hydrogen leak over time can create an explosive mixture at the highest elevation within the enclosed space. The hydrogen gas cloud in this situation will increase in size until it finds an ignition source, or it is dispersed by air currents. This is where the ventilation design of a module becomes important. It must be able to provide sufficient air movement to dilute a hydrogen release and sufficient air exchange to ensure the lower flammable limit is not exceeded.

The classification design of a hydrogen module should almost always strive for a Zone 2 classification. There must be sufficient air movement and exchange to ensure that no hydrogen accumulations can occur. The criteria for assessing the performance of a ventilation system in the context of a classification design is defined in Table D.1 of IEC 60079-10-1 "Explosive Atmospheres – Part 10-1: Classification of Areas – Explosive gas atmospheres.

Table D.1 defines the ventilation design criteria for a Zone 2 application based on the grade of release. For assessment, a secondary release is assumed because a primary release of hydrogen in an enclosed area is never a good idea. To achieve a Zone 2 classification then requires that our ventilation design provides a medium dilution criterion with some degree of availability.

The IEC standard incorporates calculation methods to determine if a ventilation scenario achieves medium dilution. It is a measure of the ventilation system's ability to dilute a release to a safe level. This is a function of ventilation velocity and the air exchange rate for the enclosed space. The availability of ventilation refers to how reliable the ventilation system can provide the necessary conditions to achieve medium dilution. We want to strive for Fair or Good in hydrogen applications. This ensures that our ventilation design is working as intended most of the time.

Table D.1 also indicates that a "non-hazardous" classification rating can be achieved with "High Dilution". This may be an option in some applications, but it requires careful consideration. This option will require very high rates of ventilation which may impact the operability of the hydrogen production unit since electrolysis is based on separating hydrogen from oxygen in water and water freezes at 0˚C. The heat load required to maintain a safe operating temperature may be significant in colder regions. Filter maintenance may also be an issue in dirty or dusty areas. If you are considering this option, be sure you have a qualified IECEx COPC Certified engineer review your application. They will ensure that this option is properly evaluated, and all options are considered in implementing a safe design.

Consider the area classification design before purchasing any major equipment. The classification design will influence the certification and marking requirements for equipment and influence the wiring installation methods. Be aware that a classification design is based on the probability of a flammable atmosphere being present in normal operation. It is not defined by the equipment installed in the location. If you classify your hydrogen production module early in the design phase and purchase your equipment knowing what the end use classification will be, you can avoid product certification or code compliance issues in later stages of a project that may impact commissioning and start-up.

A classification design should also be formally documented. This ensures that the classification design can be verified and maintained over the life of the facility. It serves as a basis for developing an explosion safety strategy that will work for your application. Reference IEC 60079-10-1 for guidance on how to document a hazardous area classification design. ■

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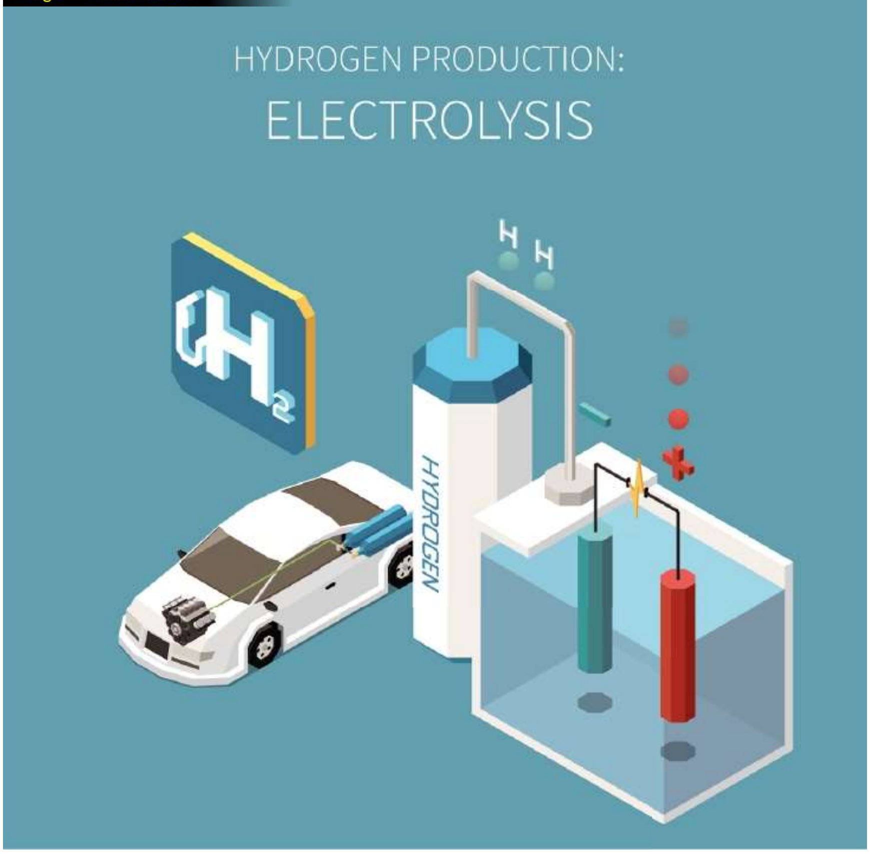

About the authors

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