hazardex

the journal for hazardous area environments

hazardexonthenet.net

October 2022

Alarms

A changing perception to alarm management

Explosion Protection

Ex d protection: explosion-proof joints

Standards

IECEx rides the hydrogen wave

Confined Spaces

Confined space entry: think beyond the obvious

Batteries

Safety concepts for battery energy storage systems

Comparison of encapsulat
powder filled methods of pr

Encapsulation of equipment (EN IEC 60079-18), or a component in a compound, has for a long time been a popular method of protection for power electronics. Powder filling (EN IEC 60079-5) offers the same level of protection (Gb) but is not so popular, yet it can have some advantages over the encapsulation method. This article looks at both methods and attempts to highlight the main differences and similarities.

Although the encapsulation standard can be used for Ga level of protection it's unusual to see this and so this article only considers a comparison for Gb protection, which is usually accepted for Zone 1 or Zone 2 applications.

Encapsulation usually involves placing the electronic PCB into a container (potting box) and then pouring a compound over it. The compound then sets to form either a hard or rubber like block. The encapsulant prevents the potentially explosive atmosphere from contact with any potential ignition sources.

Powder filling uses quartz particles or glass sand to fill the enclosure (container) instead. Although the standard refers to 'powder' filling, the term sand will be used as an alternative term in the rest of this article. The enclosure must be vibrated or tapped to shake down the sand and ensure it has settled correctly into all spaces. In order to retain the sand, the container has to be sealed up, although not air tight, at the end of the filling process. The container requires just IP54 or minimum IP43 if it is installed in a clean room. If it is completely sealed, a

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breather must be fitted. The sand does not prevent tiny amounts of the potentially explosive atmosphere reaching the internal components, but the presence of the sand quenches any ignition.

An advantage with sand filling is that it is possible to remove the sand and repair the device, change a battery, or modify the internal circuit (subject to compliance with the certificate documents) or update software etc. The device can then be refilled and returned to the customer.

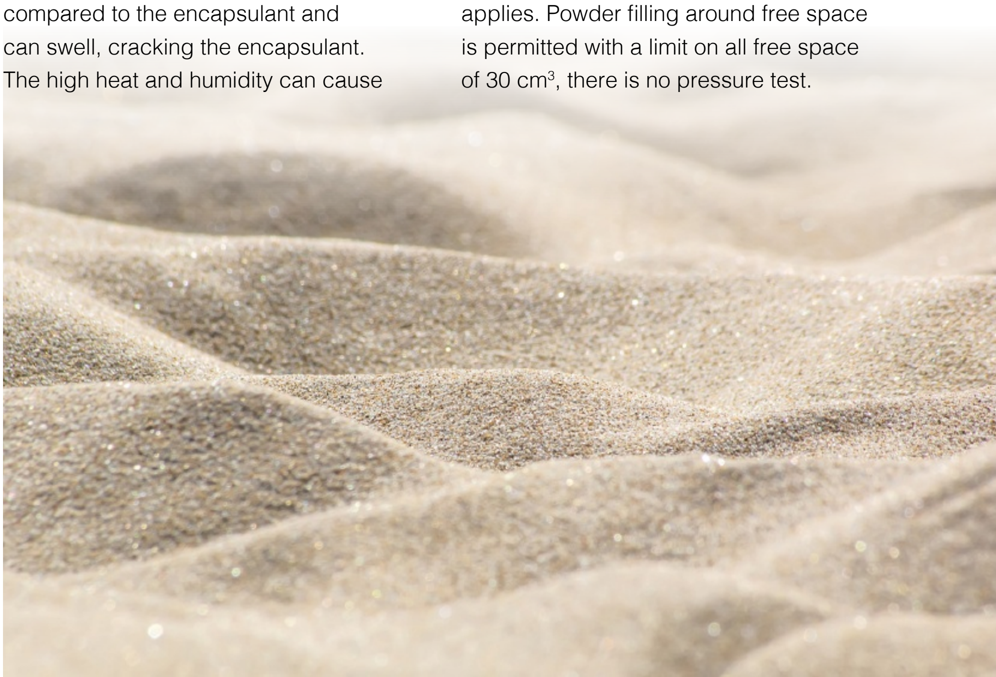
Encapsulants are subject to certain requirements which can also cause problems for compliance. The encapsulant must:

- Have a continuous operating temperature that is equal to or greater than the hottest internal component under normal operating conditions
- Pass an electric strength test through a 3mm disk
- Pass a water absorption test

The electric strength test and water absorption test do not cause a problem for modern compounds – the author has never known samples to fail these tests – but the tolerance on the thickness of the sample disks is +/- 0.2mm and the diameter is 50mm +/-2mm. As the compounds are usually poured and not moulded, this means the disks must be specially and carefully prepared. The disks are measured before the tests and often new samples must be obtained. In addition, as the encapsulated device must go through thermal endurance tests of EN IEC 60079-0, this usually involves at least two weeks in an environmental chamber at 90% humidity and 95°C, followed by a further two weeks at 20K above maximum internal component temperature. The embedded components have a different coefficient of expansion compared to the encapsulant and can swell, cracking the encapsulant. The high heat and humidity can cause swelling of the encapsulant, decomposition, discolouration, or cracking. When potted in a case, epoxy does not stick very well and often comes away, causing a gap to appear. This is a problem for any client relying on the adhesion to reduce encapsulant thickness.

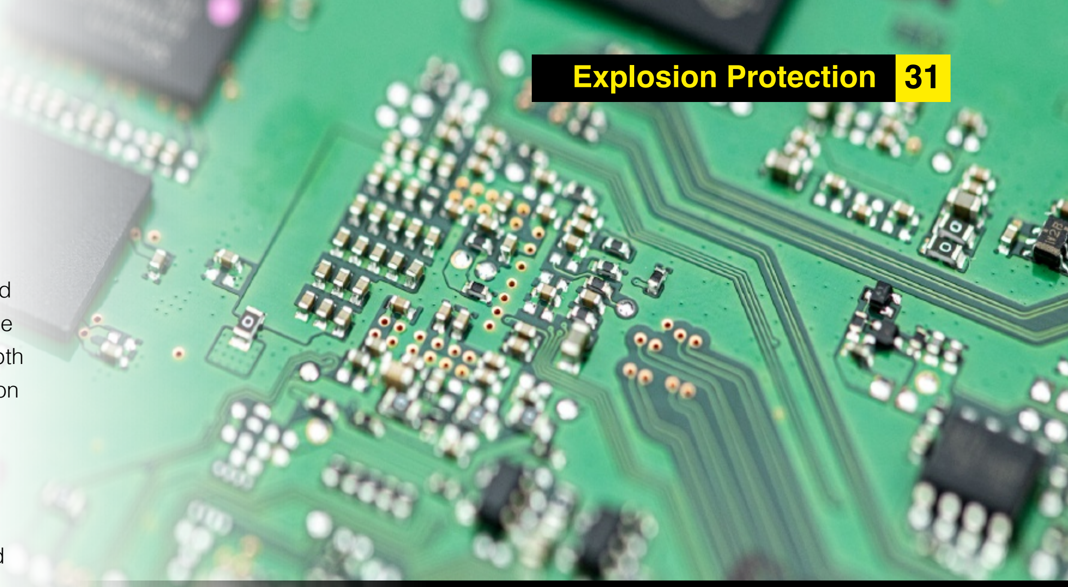
The glass sand must have particles within a certain size range, and also has to pass an electric strength test which uses two parallel plates. The test determines whether the moisture content of the sand is sufficiently low to provide good insulation. The test is also used on production to confirm the sand used to fill the equipment is also compliant. The design of the parallel probes is included in the standard. No thermal endurance test is required on the sand or on the enclosure joints unless the non-metallic contributes to the minimum IP rating of the container.

Free space is permitted in both encapsulation and powder filled concepts. 'Free space' is a term which refers to a void in the encapsulant or sand, often a relay which has a cover and must not be filled in order for it to operate correctly. In both standards there are limitations on the amount of free space permitted. If more than 10cm^3 (maximum 100cm^3) is encapsulated a pressure test applies. Powder filling around free space is permitted with a limit on all free space of 30 cm^3, there is no pressure test.



Powder filling uses quartz particles or glass sand to fill the enclosure (container) – Image: Shutterstock

Distances from the outside surface to the internal components are required in both standards. Those required to comply with the encapsulation standard can be quite complex to determine! The distances ensure there is sufficient depth of encapsulant or sand for the protection method to achieve its function.



Encapsulation usually involves placing the electronic PCB into a container (potting box) and then pouring a compound over it – Image: Shutterstock

Both standards include a fault assessment of the circuits. The fault assessment process requires a detailed knowledge of the circuit and the component values to eliminate those not subject to fault. Where the manufacturer has designed the circuit, this is easy to provide. The circuit can be designed with the fault assessment in mind and create a really robust solution. For those manufacturers utilising electronic devices from other manufacturers, the process is a lot more difficult, because the OEM is unlikely to divulge the details of the circuit. As a result, an assessment is likely to assume the vast majority of components present could fail open or short circuit, with unknown effect. The circuit can only be protected by adding a large number of thermal fuses so that if any failure occurs, the electrical supply will be disconnected. Whilst an OEM device may be an attractive option, the problems positioning the fuses and the cost of making up a set of fuses connected in series pushes up production costs for the equipment.

The powder filling standard, however, omits the fault assessment if the device is fitted with a fuse which is rated at no more than 1.7 times the maximum normal current. A temperature rise test is carried out at 1.7 times the normal current to simulate a fault in the circuit and the maximum surface temperature is determined from the result. The thermocouples are placed at points 5mm below the surface of the sand but do not touch any components if they are located a greater distance below the surface.

A pressure test is required on containers that will be sand filled, at 50 kPa, with no permanent deformation over 0.5mm permitted. This means the enclosure will need to be reasonably robust, whilst there is no pressure test on potting boxes for encapsulation, there is a pressure test on internal free space if it exceeds certain volume limits. This pressure test is at a minimum of 10 bar, higher pressure for minimum ambient lower than -20°C, unless the device can pass a restrictive breathing test according to IEC 60079-15. The test ensures the encapsulant will not crack or split, assuming gas has migrated to the internal space, formed an explosive mixture, and ignited to produce an internal pressure (see the flameproof standard where a reference pressure cannot be obtained on small enclosures).

The glass sand must have particles within a certain size range, and also has to pass an electric strength test which uses two parallel plates – Image: Shutterstock

In comparison to sand filling, the solutions required for encapsulating electronics can be a lot more onerous and costly although in some respects the powder filling standard can be more restrictive. This article has not attempted to give a full and detailed account of all the subtle differences, to make it more readable, so there are some differences that have not been highlighted. ■

About the author

David Stubbings is Technical & Commercial Consultant at Eurofins E&E CML Limited. David's career in hazardous area equipment certification spans 30 years, from the manufacture of motors and generators at GEC Alsthom in Rugby, to testing and certification of equipment for Notified Bodies EECS and Sira. David founded Certification Management Limited (CML) with Mike Shearman which was purchased by Eurofins in 2019.