Avoiding corrosion: a big instrumentation challenge

by Klaus-Dieter Meyer, Intertec

Most designers protect field process instrumentation and control equipment against the effects of its environment by using some form of enclosure. But if, as is often the case, the environment contains corrosive chemicals, the long term integrity of the enclosure can be threatened. Corrosion is a gradual, diffusion-controlled process, causing progressive destruction of metal through electrochemical reaction. For any application with a long lifecycle, it is therefore essential that the enclosure fabrication material does not contribute to, or suffer from, corrosion.

Protective integrity

Virtually all field instrumentation requires protection against environmental factors such as extreme heat or cold, wind, rain, snow, dust or sand. The specific requirements are dictated by the type of instrumentation and the climatic conditions at its location. If the atmosphere is corrosive due to the presence of natural or manmade chemicals, the equipment housing needs to be impervious to their effect, otherwise its protective integrity will be compromised.

Perhaps the most obvious example concerns offshore oil and gas exploration and production platforms, where the salt in seawater spray – which is predominantly sodium chloride (NaCl) – accelerates corrosion. The effect is exacerbated by galvanic corrosion, which occurs where dissimilar metals come into contact, such as the pipework entry ports in steel enclosures. If a sour or acid gas such as hydrogen sulphide (H_2S) or carbon dioxide (CO_2) is present, this further compounds the problem.

As companies strive to recover oil and gas from depleted resources there is a trend to design offshore platforms and coastal processing plants with a longer service life, making corrosion prevention even more of an issue. Experience of metal-based instrumentation housings in salt laden environments, which can suffer severe degradation, is leading many designers to investigate use of better enclosure fabrication materials for long life-cycle projects.

Despite increasingly stringent fugitive emissions standards, many petrochemical plants and oil refineries still create localised corrosive atmospheres. An inevitable by-product of 'cracking' heavy oil by heating it to produce lighter hydrocarbons is the production of large quantities of sulphur dioxide (SO_2), which combines readily with water vapour and oxygen to form highly corrosive sulphuric acid (H_2SO_4). Even though this is a well-known problem, many refineries still house field instrumentation in painted steel enclosures, which are particularly susceptible to rusting and H_2SO_4 corrosion, and can have a lifetime of just a few years.

It was recognition of the limitations of using metal materials for field equipment housings that led to the founding of enclosure specialist Intertec in 1965. From the outset, the company chose to base its products on glass fibre reinforced polyester (GRP), which is inherently inert and virtually immune to corrosion and the effect of atmospheric pollutants such as NaCl or H_2SO_4. It is also resistant to a wide range of petrochemicals, including benzene, butylene, ethylene, napthalene, propylene, toluene and xylene. As a building material for environmental protection enclosures, it has numerous advantages over metal. Almost as strong as stainless steel but with only a quarter of its weight, GRP has a much higher thermal resistance – making it easier to insulate against heat and cold – and because the material is an electrical insulator, it does not contribute to galvanic corrosion.

Proven longevity

The longevity of GRP enclosures, cabinets and shelters is well proven. To date, the company has produced over a million protective housings, many of which are sited in areas where corrosive chemicals are present in the atmosphere. As an example, there are more than 4,000 Intertec GRP enclosures and cabinets installed at the Al Taweelah seawater desalination and power plant in Abu Dhabi. Many of these have protected instrumentation for more than 20 years, and show no sign of degradation despite prolonged exposure to salt and very high levels of UV radiation from the sun.

Another example of the resistance of GRP enclosures to salt comes from the Irving Oil refinery in Saint John, New Brunswick. This is Canada's largest oil refinery, and Intertec supplied nearly all its instrumentation enclosures. Many of these have been in service for as long as 30 years, and show little evidence of ageing, other than a slight roughening of surface finish – which is often referred to as 'chalking' or ‘frosting’. This is despite a particularly hostile climate, combining salt air with very hot summers, extremely cold winters and rapid changes in temperature; during spring, the temperature can change by as much as 40˚C in a single day.

The long-term immunity of GRP enclosures to damage from petrochemical media is demonstrated at the Bayernoil refinery complex in southern Germany. When the oil refinery was first constructed in the mid 1960s, Intertec supplied a large quantity of two-part enclosures to protect process transmitters distributed across the site, as well as cabinets for larger instrumentation clusters. Following a recent instrumentation upgrade, a number of these original enclosures became available for detailed inspection and analysis, allowing Intertec to assess the effect of long-term exposure to SO_2 and H_2SO_4 on GRP.

Figure 1: Despite 40 years’ exposure to an atmosphere containing sulphuric acid, after cleaning (bottom right), the surface of this GRP enclosure is unblemished.

Figure 1 shows a Multibox enclosure containing pressure regulation and temperature monitoring instruments that had been in continual service at the refinery’s cracker furnace for more than 40 years! No maintenance had been carried out on the enclosure – nor was it needed – during this time. Although there is surface rust on some of the pipework connections and mountings, the instruments are clearly still functional and the lid seal is intact. Aside from requiring a new window seal, the enclosure itself has suffered no degradation; the close-up view shows that after cleaning, its surface is free of blemishes.

Figure 2: The gel coat of this GRP cabinet is still intact and there are no loose fibres, 40 years after installation at an oil refinery.

Although these field protection housings are constructed almost entirely from GRP, they inevitably include some metal components, such as internal instrumentation support rails, door hinges and clasps, and external mounting clamps. For corrosion resistance, Intertec manufactures all these components from 316 stainless steel or hot-dip galvanized metal. Figure 2 shows a large cabinet from the Bayernoil refinery, containing fluid sighting tubes. Again, there is no sign of material degradation – note the absence of any corrosion around the door hinges or lock mechanism – and close-up examination reveals that the surface finish is much the same as when it was manufactured over 40 years ago, with no loose fibres.

Enhanced protection

Research into the ageing effect of weather on GRP has shown that in the main, any long-term degradation is caused by mechanical forces and not by chemical interaction between the material and its environment. Over time, the combined effect of UV-induced surface embrittlement, water diffusion and erosion can cause bundles of glass fibres to be exposed, rendering them susceptible to direct water ingress. Repeated expansion and contraction of the water then causes cracks, which eventually penetrate deep into the material.

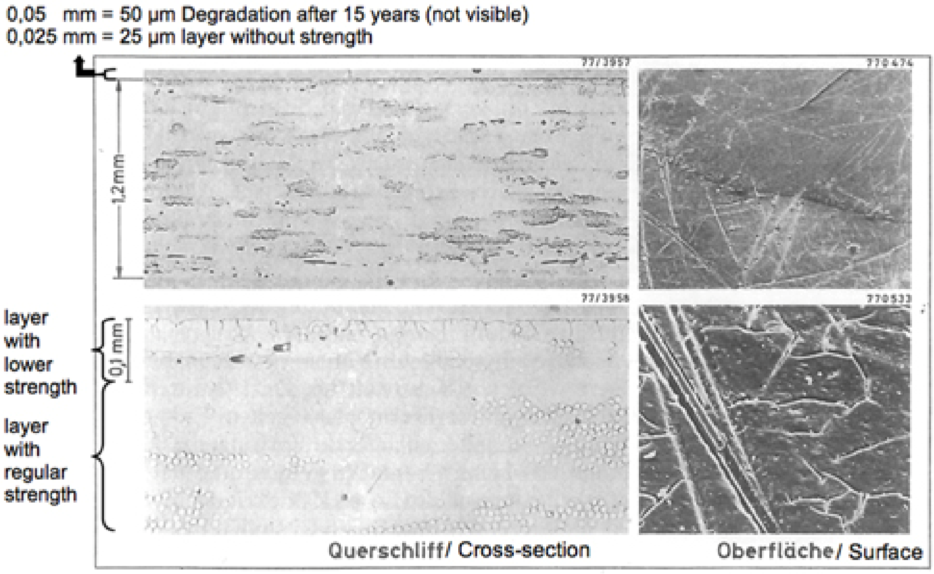

Figure 3: The cross-section and surface of a GRP sheet after 15 years' exposure to the weather (*courtesy of Kunstoffe Magazine: Schädigungsmechanismus an GFK-Oberflächen bei Freibewitterung, Von Chem.-Ing. Dankmar Scholz*)

The scanning electron microscope images in Figure 3 show the cross-section and surface of a nominally 1 mm thick GRP sheet (of a type used by Intertec, but without the protective coating that Intertec applies) after 15 years' exposure to the weather. About 50 micrometres has been eroded from the surface, which is further damaged to a depth of 20 to 30 micrometres. These results can be linearly extrapolated; after 50 years approximately 250 micrometres will have been removed from the surface, with damage extending to a depth of about 80 micrometres. In other words, the sheet's effective thickness will be reduced from 1 mm to 670 micrometres, with a proportionate loss in strength of about 30%.

However, virtually all Intertec protective housings – regardless of whether they are constructed with a single wall or a double wall containing a polyurethane foam core – utilise GRP sheeting that is at least 4 mm thick. Even after 50 years, surface degradation will only reduce the effective thickness of the sheeting to 3.67 mm and result in a strength loss of about 8% – a negligible amount that has no affect on the housing's structural integrity.

For maximum long-term protection, this marginal weather-induced damage can be prevented by applying a layer of UV resistant gel coat to the surfaces of GRP panels. The chemical composition and thickness of the gel coat are critically important to an enclosure's long term stability; any differences between thermal expansion, for example, could cause the coat to 'creep' and undergo excessive thinning.

Intertec uses a specially-developed pre-accelerated gel coat that fully matches the properties of GRP. Made of unsaturated polyester resin, it is applied as a spray before the polyester in the GRP panel is fully cured. The base component is a pure isophthalic acid resin, dissolved in styrene and HEMA (Hydroxyethylmethacrylate) monomer – the styrene content is about 30%. The gel coat chemically bonds with the polyester resin of the GRP panel; after curing, it provides an extremely durable, but flexible, surface finish with a high resistance to weathering and hydrolysis loads (this kind of coating is also widely used in boatbuilding). The gel coat is also much more resistant to UV than plastic materials, such as the acrylic paints used by many metal cabinet manufacturers.

To maximise UV protection, Intertec applies a thick gel coat surface layer. Depending on the housing's intended location and environment, it is typically between 400 and 800 micrometres (0.4 to 0.8 mm) thick. In contrast, the typical thickness of paint sprayed on steel enclosures is only 50 to 70 micrometres – an order of magnitude less. Even the acrylic paint finish of cars and trucks is generally only 70 to 80 micrometres thick!

The only degradation that occurs with this gel coat is a very slight thinning over time, due to the effect of UV radiation. Typically, this only amounts to perhaps 100 micrometres (0.1 mm) over 30 years and has no effect on the housing's structural integrity, stability or function. Even under extremely hostile conditions that combine very high UV levels with sand or dust storms, which slightly increase gel coat loss rate through abrasion, there is no change in the performance of the underlying cabinet or shelter. For example, over the past few decades Intertec has supplied thousands of shelters for protecting instrumentation at oilfields in desert regions such as the Middle East. None of these has suffered material degradation, other than a slight chalking of surface finish.

Guaranteed performance

Having manufactured GRP-based field protection enclosures, cabinets and shelters for nearly 50 years, Intertec has acquired extensive empirical evidence to demonstrate its contention that GRP is a far more suitable material than metal for most outdoor field instrumentation protection applications, especially for projects with long life cycles, harsh media and where corrosion and UV exposure need to be considered.

Figure 4: Intertec's latest Multibox Vario enclosures are produced to millimetre accuracy by a CNC-based manufacturing process.

Continual research and development has enabled Intertec to progressively extend the life, performance and diversity of its products, and the company now offers one of the most extensive ranges of heating, cooling, fire-safe and explosion-proof field protection solutions in the industry. Improvements in materials, such as stronger GRP epoxy resins, foam insulation with lower heat transfer coefficients and new formulations of gel coat with even higher UV resistance, have been combined with advances in production technology that ensure very tight control of the manufacturing process. Nowadays, for example, the company employs a patented CNC-based manufacturing process for its popular Multibox Vario enclosures (Figure 4) that shortens design and production times significantly. Using special software on Intertec's website, instrumentation engineers can configure an application-specific housing to millimetre accuracy and import the data into their CAD system for layout optimisation; the same data is subsequently used to control automated manufacture of the housing.

As a result of its experience and expertise with GRP materials, Intertec guarantees that all its field cabinets and shelters have a working lifetime of at least 30 years under normal industrial conditions. These normal conditions include environments where salt, sour gas or sulphuric acid are present in the atmosphere – such as the offshore oil or coastal processing plants where many instrumentation engineers and metallurgists are currently investing a lot of time and energy in specifying and adopting improved materials to extend equipment lifecycles.

About the author

Klaus-Dieter Meyer is Vice President of Intertec-Hess GmbH and has worked for the company since 1992. His previous experience includes a 15-year tenure with Linde Engineering in Germany, which designs and builds large-scale chemical plants for the production of industrial gases. During his time with Linde, Klause-Dieter held a number of key project and departmental management positions, including Head of Sales for Environmental Technology.

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