STEM-Corrosion™

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Where do We Prefer Failure: Nowhere, Field, or Laboratory?

The phrase "Failure is not an option" is often associated with success of Apollo 13 moon landing mission.

The time-tested and proven approach to avoid failures during operation stage is to simulate failures under controlled environment during design and manufacturing stages. Laboratory and simulation tests thus play vital role in establishing safe operating envelopes.

The laboratory tests should simulate extreme field conditions but not extreme conditions in which anything and everything would fail. The laboratory methodologies may be ranked using a logarithmic formula:

- log (laboratory/field) > 0

If the logarithm value of a laboratory methodology is positive and closest to zero, it is the top ranked methodology:

- Rank 2 (Test is far more severe than field conditions and may fail anything and everything)
- Rank 1 (Test is more severe than field conditions)
- Field conditions
- Rank 3 (Test less severe than field conditions)
- Rank 4 (Test is so mild that anything and everything will pass).

Most practical, economical, and reliable laboratory methodology is the Rank 1 methodology. Rotating cage for evaluating corrosion inhibitors in the oil and gas industry is the Rank 1 methodology, i.e., severe but just right! Any inhibitor that passes this methodology will do well in the field and any inhibitor that fails in this methodology will fail in the field. Reliability, repeatability, and reproducibility of rotating cage have also been established through ASTM G202 Standard Test Method.

Atmospheric pressure rotating cage apparatus meeting the requirements of ASTM G202 apparatus as well as corrosion coupons that fit in rotating cage are available from **Metal Samples**.

Top Influencer of This Newsletter:

Günter Schmitt

My Story

My scientific career started in 1973 with mechanistic studies in CO_2 corrosion of steel, and since that time and through all the years up to today CO_2 corrosion made an essential part of my R&D activities and industrial consultation. Over the 5 decades the focus changed but the subject CO_2 never lost its charm. Today with the upcoming hydrogen technology CO_2 is about to become a raw material for organic base chemicals and intermediates up to polymers. In a green industry the hydrogenation of CO_2 will gradually substitute fossil raw materials. This industrial transformation will teach us again that technological processes are not possible without materials with appropriate properties in a multitude of different environments. Corrosion resistance will be one of the basic properties of materials, and its evaluation will continue to be an essential part of technological development and progress. Thus, CO_2 and hydrogen corrosion will keep experts busy for the next centuries.

Like with CO_2 also corrosion systems containing H_2S, elemental sulfur and hydrogen ran like red ribbons through my R&D life, including failure prevention by materials selection, inhibition and protective coatings. For all the challenges involved, the chemistry background of my university education turned out to be ideal for finding interdisciplinary problem solutions.

Since 2005 I am CEO in the IFINKOR - Institute for Maintenance and Corrosion Protection Technologies n.f.p.Ltd. in Iserlohn, Germany, an independent institute at (not in) the Iserlohn University of Applied Sciences, specialised in corrosion protection technologies and bridging the gap between academia and industry by laboratory R&D, knowledge transfer and consulting. The unique feature of IFINKOR is the availability of high pressure, high temperature equipment applicable for critical media like hydrogen sulphide, hydrogen, carbon dioxide, concentrated acids or ammonia, even under controlled flow conditions.

My Style

There is nothing in natural and engineering science which is not fascinating. Broad interdisciplinary knowledge is the basis for innovation and smart solutions. If I want something, I know that I can achieve it – with a good and motivated team. The team is winning, not the individual.

Greatest Contribution

Within decades of R&D in chemistry and corrosion science and technology I can think of several achievements on which I am proud of.

A highlight in the mid 70s was the finding why production wells for highly sour, elemental sulfur containing natural gas experienced perforation within 3 months in the presence of a sulfur solvent and how this catastrophic corrosion could easily be stopped by inhibition without changing much in the production process. The failure mode was reproduced in the laboratory under service related high pressure H_2S conditions, likewise the evaluation of the inhibitor. This corrosion prevention method, applied still today, saved the German oil and gas producing company (today ExxonMobil) many millions of German Marks.

In the 80s we developed the methodology to use glass vessels for testing corrosion inhibitors in high concentrated mineral acids needed for acidizing jobs in sour gas wells at temperatures up to 150°C and H_2S pressures up to 30 bar, i.e. under conditions which easily ruin even high alloy autoclaves. The highly versatile methodology allows electrochemical measurements under extreme conditions, including supercritical environments. This unique approach helped us many times to cope with experimental challenges that would otherwise hardly be manageable.

A highlight in the late 80s was when our experimental investigations resulted in the mechanistic understanding of elemental sulfur corrosion of steel which led to the publication of methodologies for meaningful corrosion tests in the presence of elemental sulfur. This publication is still cited in the current edition of ISO 15156/NACE MR0175, the “bible” for materials selection in sour oil & gas corrosion systems. The message of the publication will be included in the presently drafted “rewrite” of this standard.

Over the years flow induced localized corrosion (FILC) and its inhibition was continuously subject of R&D activities in my group. Several experimental tools were developed and/or applied, among them the rotated cage, the submerged impinging jet, the gas-pulsed impinging jet and pipe flow in single und all multiphase modes. In all cases the focus was on the quantification of applied flow intensities in correlation with the initiation of FILC by flow dynamic destruction of protective scales. The breakthrough came in the early 2020s with our concept of “Freak Energy Density”, which, in analogy to the Freak (Rogue) Waves on the oceans, assumes singular events of energy-rich near-wall turbulence elements in the fluid directed perpendicular to the wall. An electrochemical methodology, developed to quantify freak energy densities in different flow regimes, revealed that such singular events can surpass the fracture stresses of protective scales on metal surfaces and, thus can initiate FILC. Corrosion inhibitors together with supramolecular structures like micelles or different kinds of polymers can reduce freak energy densities by energy dissipation of near-wall turbulence elements below the fracture stress of scales and, thus, can prevent the initiation of FILC. We now understand that the protection mechanism of functional additives in flow systems is based both on adsorption and drag reduction.

Pinnacle Moment

It is difficult to define one pinnacle moment in a 50 years academic career. R&D is always linked to enthusiasm and frustration, successes and failures, highs and lows. Success after a series of failures typically yields a pinnacle moment and such situation happened quite a few times in my professional life. Another level is the recognition of scientific and technical successes by a scientific and technical community. On this level I experienced a pinnacle moment when I was awarded the European Corrosion Medal from the European Federation of Corrosion in 2011, when I received the Lee Hsun Lecture Award from the Chinese Academy of Sciences in 2018, and when I was honored with the W.R. Whitney Award from NACE International in 2020. It was a very special feeling when I was elected in 2014 by the international corrosion community to become 1st Vice-President and in 2017 President of the International Corrosion Council. Thus, I can proudly admit that I experienced more than one pinnacle moment, on different levels.

Advice to Industry

There was a time when the leader of a chemical company was a chemist and the leader of an engineering company was an engineer. In these days it was agreed that R&D projects need capable experts, appropriate financial support, and reasonable time for its execution. It was accepted that not every fishing throw catches a fish and that success needs time. Today the leader of a chemical or engineering company is an economist or a lawyer. For them all knowledge is already available, technical solutions can be harvested from experts for nothing, R&D is unnecessary or needs to be paid by public funds, R&D only entertains scientific-technological nerds which search in fields with no interest to industry.

This picture is certainly exaggerated, but it basically describes reality correctly. Deciders in today's industry should accept that investing in R&D (not only in the own company but also in independent institutions) is investing in solutions of future problems. This means thinking in life cycle costs and not only in terms of money spent today. In the field of materials corrosion and surface protection this means reducing maintenance costs by investing more in R&D for advanced asset protection and real-time status monitoring. This means support of academic groups and institutes which educate and search in the field of corrosion and materials protection, the importance of which is still widely underestimated. Therefore, the installation and continuation of such groups needs increasing support as their number is presently decreasing in many countries, not only due to retirements of experts. My advice to the industry: support and invest in young people by joint projects and bilateral knowledge transfer and help them in growing in the field of corrosion.