Effectively counteract corrosion and protect asset integrity
MITIGATE CORROSION, MAXIMIZE PRODUCTION, AND MINIMIZE RISK

Acidic gases such as carbon dioxide and hydrogen sulfide as well as organic acids dissolved in produced water will corrode carbon steel tubing, vessels, and pipelines if left untreated.

Failure to control corrosion rates can have catastrophic consequences, potentially resulting in environmentally damaging leaks and compromising personnel safety.

As part of the PREVENT suite of trusted products and services to preempt and mitigate production issues, Schlumberger delivers a comprehensive portfolio of chemical treatments to preserve asset integrity.

These treatments are ideally suited for all production conditions across the world to tackle all types of corrosion—regardless of environmental, production, or geographical challenges.

- Carbon dioxide (CO$_2$) and hydrogen sulfide (H$_2$S) corrosion inhibitors
- Hydrotest products
- Cooling water corrosion inhibitors
- Environmentally acceptable corrosion inhibitors
- Batch corrosion inhibitors
- High-temperature corrosion inhibitors
- Gas corrosion inhibitors
- Multifunctional products (combined scale and corrosion inhibitors)
- Oxygen (O$_2$) scavengers
- H$_2$S scavengers
- Oil and gas pipeline inhibitors
- Subsea and deepwater corrosion inhibitors
THE TRUSTED APPROACH TO COMBAT ALL TYPES OF CORROSION

In oil and gas production, corrosion manifests itself in various forms, including localized, general, underdeposit, and galvanic. It generally takes place where water is present, with the rate affected by variables including CO$_2$, H$_2$S, and O$_2$ concentration; temperature; pH; water cut; salinity; pressure; and flow velocity.

**Inhibitor application**

Corrosion inhibitors can be applied anywhere in the production system—downhole; at the wellhead, production manifold, or gathering and export pipelines; and in produced water reinjection systems.

They are normally applied either continuously or via batch treatment. In all applications, corrosion monitoring is vital to monitor performance and optimize cost.

Before deploying an inhibitor, a number of factors are considered:

- **Method of application**
  This depends on several parameters, including system conditions, injection location, and the availability of chemical injection equipment.

- **Solubility**
  Inhibitors are generally classified as being oil-soluble, water-soluble, or oil-soluble and water-dispersible.

- **Emulsification and foaming tendencies at the required dose rate**
  These must be assessed to ensure product stability under typical storage temperatures for prolonged periods and at injection temperature.

- **Compatibility**
  The compatibility of corrosion inhibitors must be evaluated versus the system metallurgy and other process additives.
DETERMINING THE BEST APPLICATION FOR MAXIMUM INHIBITION EFFECTIVENESS

Schlumberger carries out field evaluation and laboratory testing to replicate field conditions and to define and determine the most effective corrosion inhibition strategy and chemical deployment approach, optimizing performance and cost-effectively protecting asset integrity.
Laboratory testing
Schlumberger uses an array of laboratory tests to deliver the most effective results. These include

- **Kettle test**
  The Kettle, or bubble, test is a quick, straightforward procedure that is typically performed at ambient temperatures up to 200 degF [95 degC]. The brine, or brine and hydrocarbon, test fluids are normally saturated with a CO$_2$ or a mix of CO$_2$ and H$_2$S. The test calculates inhibitor efficiency based on corrosion rates before and after inhibitor injection.

- **Rotating cylinder electrode (RCE) test**
  The RCE test evaluates inhibitor performance under moderate flow conditions. It uses the same principles as the kettle method, except that the specimen electrode is mounted on a shaft that is rotated at up to 10,000 rpm, showing shear stresses of up to 100 Pa on the electrode.

- **Rotating cage autoclave test**
  This test—also known as a high-shear autoclave test—assesses inhibitor performance under very high shear conditions using an autoclave that contains the fluids to be evaluated. The test can assess inhibitor performance in both sweet and sour conditions at temperatures of up to 400 degF [200 degC] and pressures of up to 1,450 psi.

- **High-pressure, high-temperature (HPHT) autoclave test**
  This static test uses coupon weight loss to determine the corrosion rate under sweet or sour conditions. Coupons are placed in an autoclave containing test liquids, and the vessel is heated and pressurized to the required level.

Field evaluation
A corrosion sidestream apparatus is used to assess inhibitor performance in the field. The sidestream unit attaches to the production system, typically downstream from the separators, and the separated water passes through it.

The corrosion rate of the produced water is measured using linear polarization resistance or Cormon CEION® high-resolution probes for oily waters. The sidestream is also used to optimize the dose rate of the inhibitor as well as to evaluate the performance of several chemicals.

Measuring the system iron concentration before and during inhibitor injection can also assess inhibitor performance.
Firmly established at the forefront of technology, Schlumberger is a recognized innovator with a proven track record in the development of new environmentally sensitive inhibitor chemistries that improve efficiency.

Global technical expertise is underpinned through a research laboratory in Stavanger. Additionally, state-of-the-art corrosion-testing equipment and unrivaled strength in ecotoxicity testing are delivered through good laboratory practices (GLP) -approved laboratories in Houston and Bergen, Norway.

Efforts are coordinated to provide routine testing and evaluation of new and existing products to drive continued progress. Ultimately, this results in a genuinely unique offering to assess, manage, and deliver excellence in production technologies.
FEATURES AND BENEFITS

Corrosion inhibitors

■ Preserved asset integrity by preventing all forms of corrosion on casing, tubing, and surface equipment

■ Specifically formulated organic compound composition that forms a protective film on the surface

■ Option of direct addition to production fluids without special mixing equipment or agitation

■ Chemical stability and formulation to accommodate temperatures to 350 degF [177 degC]

■ Easy handling on location even at –45 degF [–50 degC]

■ Enhanced QHSE and environmental profile to meet stringent requirements

Testing services

■ Laboratory simulation under field conditions to ensure optimal product performance

■ Evaluation of products electrochemically and with coupons to evaluate surface effects and inhibitor effectiveness

■ Sidestream apparatus used in the field to assess performance under high-shear and high-temperature conditions

■ Subject to a wide range of ecotoxicological tests
GLOBAL SOUR TESTING FACILITY. NISKU ALBERTA
DETERMINING THE BEST APPLICATION FOR MAXIMIZED EFFECTIVENESS

An established leader in asset integrity, Schlumberger carries out laboratory testing replicating field conditions to define and determine the most effective corrosion inhibition strategy and chemical deployment approach, optimizing performance and cost-effectively protecting asset integrity.

Complementing its existing world-leading capability with kettle, RCE and autoclave tests, and against the backdrop of rapid growth in global demand for sour corrosion prevention, Schlumberger constructed a laboratory in Nisku, dedicated to the mitigation and prevention of corrosion in H₂S environments.

The laboratory, used by global Schlumberger teams to support product selection and development for international deployment, houses high pressure, high temperature vessels used to evaluate and develop corrosion inhibitors for a comprehensive range of producing conditions.

Testing equipment includes

- six 1.25-litre-capacity Hastelloy C-276 construction HTHP autoclaves with electrochemical and weight-loss measurement capability, which can test to a temperature of 300°C and a pressure of 35,000 kPa
- two 1-galUS-capacity Hastelloy C-276 construction HTHP autoclaves with weight-loss measurement capability for high shear applications (up to 200 Pa), which can test to a temperature of 300°C and a pressure of 35,000 kPa
- six 1-litre kettle test cells for atmospheric pressure and low- to intermediate-temperature applications
- A noncontact profilometer with a rotational module for three-dimensional imaging of corroded metal specimens
Laboratory safety
Schlumberger has a long-standing HSE commitment to the highest standards for the health and safety of its employees, customers, and contractors.

In line with Schlumberger’s focus on reliably and accurately performing all operations without compromising security, safety, and quality, the sour laboratory’s heating, ventilation, and air conditioning (HVAC) system as well as its power services are independent from the rest of the building.

Pioneering research and development
Firmly established at the forefront of technology, Schlumberger is a recognized innovator with a proven track record in the development of new environmentally sensitive inhibitor chemistries that improve efficiency.

Global technical expertise is underpinned through the Stavanger research laboratory, which includes state-of-the-art corrosion-testing equipment and unrivaled ecotoxicity testing capabilities, delivered through Good Laboratory Practice (GLP)–approved laboratories in Houston and Bergen, Norway.

Efforts are coordinated to provide routine testing and evaluation of new and existing products to drive continued progress. Ultimately, this results in a unique offering to assess, manage, and deliver excellence in production technologies.
Case Study

COUNTERACTING CORROSION IN HIGH-PRESSURE SOUR PIPELINES

CHALLENGE

H₂S and high pressure posed a severe corrosion risk to an operator’s extensive network of pipelines, which were more than 15 years old and transported production from more than 11 field satellites to the processing plant. The unmitigated corrosion rate in the field was around 21 mpy.

SOLUTION

Extensive autoclave testing determined the appropriate batch chemistry. To avoid excessive chemical use, Schlumberger also determined the maximum dilution ratio for the selected batch corrosion inhibitor—KI-3866* corrosion inhibitor.

The customer began using KI-3866 as the main batch corrosion inhibitor for the field, with 24 lines batched on a quarterly basis. Schlumberger installed flush-mounted coupons at the high-pressure sour gas inlet and the lower-pressure sour gas inlet.

RESULTS

The KI-3866 inhibitor outperformed previous products, lowering program costs and reducing the corrosion rate by 97% to less than 1 mpy.

Since the inhibitor was installed, no pitting has been observed on the coupons, and general corrosion rates have not exceeded the NACE corrosion rate of 1 mpy (0.025 mm/y).
ChALLENGE
A number of pipelines producing from the Duvernay, Montney, and Nordegg zones in Western Canada were at significant risk of general and localized corrosion due to CO$_2$ and H$_2$S in the produced fluids. Linear polarization resistance (LPR) probe data measured untreated corrosion rates as more than 150 mpy. There was also a risk of underdeposit corrosion in the pipelines due to accumulation of iron sulfide on the pipe surface.

A robust and consistent corrosion-mitigation strategy was required across all 47 pipelines.

SOLUTION
To minimize the logistical challenges, the operator requested that one corrosion inhibitor be used in all of the pipelines. Several new inhibitors were formulated, and their performance assessed throughout a rigorous laboratory testing program.

The KI-3108* corrosion inhibitor, which successfully mitigated general and localized corrosion in the laboratory tests, was recommended for use in the field. It was continuously injected based on water production.

A pigging program was designed and implemented to remove any iron sulfide deposits from the pipeline and to prevent underdeposit corrosion.

RESULTS
Following optimization of the dose rate, the KI-3108 inhibitor reduced the corrosion rate to less than the target 5 mpy (0.13 mm/y). Similar rates were also found for the weight-loss coupons, and there was no evidence of localized corrosion.

Subsequent in-line inspection found no significant metal loss or deformation of the pipelines.
A full service offering to maintain and restore full production.

Schlumberger production technology specialists deliver targeted, integrated strategies that help to decisively remediate production issues such as deposit formation and naturally occurring gases, enabling customers to safely restore and improve flow performance and revenue while avoiding costly repairs and shutdowns.

Firmly established at the forefront of technology, Schlumberger has a full service offering that integrates pioneering chemical and process solutions, equipment, and software with unrivaled technical expertise.

Working with the world’s largest oilfield services provider, customers benefit from a truly unique combination of outstanding technological capabilities and improve their understanding of how to successfully address production challenges in an increasingly competitive marketplace.

The team’s global footprint and extensive suite of technologies helps customers to reliably, safely and efficiently maximize production—regardless of system complexities or geography.
MAXIMIZE PRODUCTION FROM RESERVOIR TO REFINERY