



Application Answers: *Corrosion Control in Membrane Nitrogen Systems*

CorrFoam 1 Corrosion Inhibitor

Challenge

Some amount of oxygen is almost always present in fluids used in *Controlled Pressure Drilling (CPD®)* operations; therefore, an effective fluids program is needed for protecting downhole tubulars and surface equipment from corrosion.

During *CPD* operations, nitrogen or compressed-air injection gas is injected into the fluid stream to create a low-density, underbalanced environment. An inert gas, like nitrogen, is preferred because it diminishes the flammability of hydrocarbon gas or condensate in the presence of oxygen, thus preventing the conditions for downhole combustion. Nitrogen is typically obtained in one of two ways:

- Delivered in high-purity cryogenic liquid form at typical concentrations of 99.99+ percent
- Generated on site with compressors and membrane units, which separate a large portion of the oxygen from the air, producing mainly nitrogen in concentrations of 92 to 96 percent

Membrane generation is often preferred because it is safer and more cost effective than cryogenic nitrogen, but it also has more residual oxygen.

CorrFoam 1 corrosion inhibitor effectively protects downhole tubulars and surface equipment from corrosion during *CPD* operations.



Constraints

- Regardless of the method of generating nitrogen for CPD® applications (underbalanced drilling, managed pressure drilling, or air drilling), the gas will contain some amount of oxygen.
- Having trace oxygen content, both cryogenic and membrane nitrogen are corrosive if not inhibited.
- Industry guidelines indicate that as little as 40 to 50 parts per billion (ppb) of oxygen can cause corrosion problems if not chemically inhibited or otherwise addressed.
- With either uninhibited cryogenic or membrane nitrogen at elevated temperatures, pitting can occur, with corrosion rates increasing with temperature.

Answer

To avoid the use of the more expensive and risky cryogenic nitrogen, a corrosion inhibitor for use with membrane nitrogen is needed. Test results show that when membrane nitrogen is used in conjunction with Weatherford's CorrFoam 1 inhibitor, corrosion rates are reduced, even at elevated temperatures. Corrosion rates are even lower than the results obtained from tests using high-purity cryogenic nitrogen.

When added to the fluid system, Weatherford's CorrFoam 1 corrosion inhibitor physically reacts with the metal surfaces of the coiled tubing, drillpipe, casing, and downhole hardware to form a protective inhibitive layer—a process known as *passivation*. Because passivation occurs quickly, the metal is not exposed to corrosive elements for extended periods of time. As a result, corrosion in oxygen-rich environments is effectively inhibited, and use of the preferred membrane nitrogen becomes operationally advantageous.

Features, Advantages and Benefits

- Weatherford's CorrFoam 1 corrosion inhibitor effectively inhibits corrosion in an aerated, oxygen-rich environment, even at elevated temperatures of 250°F (121°C) or higher. The long-term corrosion protection that it provides over a wide range of environments maximizes operational flexibility.
- CorrFoam 1 corrosion inhibitor reacts with downhole metal surfaces to quickly form a protective inhibitive layer, providing inhibition even in rapidly changing conditions.
- This durable inhibitor reduces corrosion to low levels even in high oxygen concentrations, enabling the use of membrane-generated nitrogen in CPD operations.
- Compatible with virtually all water-based systems, CorrFoam 1 can be used in air, mist, foam, and two-phase fluids for underbalanced and managed pressure drilling.



Laboratory Results

To understand the corrosive effects of cryogenic and membrane nitrogen, Weatherford conducted a detailed investigation of the two technologies at the company's Chemical Research & Development Center in San Antonio, Texas.

The investigation focused on standard weight-loss corrosion tests at varying oxygen levels, including typical streams of cryogenic 99.9999 percent nitrogen and membrane nitrogen in concentrations of 92 to 96 percent. Tests were run at elevated temperatures of 250°F and higher, using foams and aerated fluids that simulated typical CPD® conditions.

The results showed that both cryogenic and membrane nitrogen are corrosive if not inhibited. Corrosion can occur at 40 to 50 ppb; therefore, both cryogenic (1 ppm oxygen) and membrane nitrogen (40,000 ppm oxygen) should be inhibited to reduce the corrosion of downhole hardware and surface equipment.

When drilling with cryogenic or membrane nitrogen injection gases, fluid should be inhibited at all times with a product like Weatherford's CorrFoam 1 corrosion inhibitor, which has been proven to reduce corrosion rates to an acceptable level and eliminate pitting.



Three corrosion coupons from the comparative investigation in Weatherford's San Antonio lab: Results from use of uninhibited cryogenic nitrogen (left), uninhibited membrane nitrogen (center), and inhibited membrane nitrogen (right).

