DURACOIL 95
SOUR TESTING

FET | Global Tubing

DURACOIL IN SOUR ENVIRONMENTS

To understand the effect of H2S on quenched and tempered Coiled Tubing, Global Tubing DURACOIL 95 grade was tested in several sour environments.

The effect of H_2S on Coiled Tubing - Sulfide Stress Cracking

Sulfide stress cracking (SSC) is a form of cathodic cracking through hydrogen embrittlement. Susceptible alloys, especially steels, react with hydrogen sulfide (H_2S), forming metal sulfides (MeS) and atomic hydrogen (H+) as corrosion byproducts. SSC occurs when atomic hydrogen diffuses into the metal but the ions can recombine to form hydrogen gas and cause damage to the steel crystal lattice. This reduces the ductility and formability of the metal, which is termed hydrogen embrittlement. Several factors influence SSC: steel composition, heat treatments, microstructure, mechanical properties, pH, H_2S partial pressure, mechanical stresses, temperature, and time. High yield strength steels (ultimate tensile above 100,000 psi or ~700 MPa) are more susceptible to SSC, since their microstructure is particularly sensitive to the effects of H_2S exposure.

Understanding Partial Pressure

Partial pressure of a gas is the pressure exerted by one among the mixture of gases that occupies the same volume. Partial pressure for H_2S is the product of total pressure by the fraction of H_2S present. For example, if the pressure is 10,000 psi at 8 ppm H_2S concentration, the partial pressure is 0.08 psi. The partial pressure of H_2S is used to set production environment limits for carbon steels, low-alloy steels, and corrosion-resistant alloys. The NACE standards relate to an H_2S partial pressure of 0.05 pounds per square inch absolute (psia). Steel used in these environments without inhibition and below 22HRC should be resistant below 0.05psi (0.3kPa), but since these codes are designed for static environments, coiled tubing operations should always use inhibition when sour environments are present.

As a way of illustration, the Ghawar field in Saudi Arabia (the biggest conventional oil field in the world), produces up to 40 mole % H_2S. However, CT interventions are usually restricted to 10 mole % H_2S, with surface pressures averaging 3,000 psi (206.8 bar) in some areas, this equates to 300psi (20.7 bar) of H2S partial pressure.

Overview of DURACOIL 95 Testing in H_2S Environment

Our testing procedure used NACE solution A for exposure of full tube specimens, which were subsequently bend-fatigue tested to simulate a field application. This process is consistent with the testing outlined in SPE 130279 and has been used for decades.

- Tube ends capped to isolate pipe internals from outside environment (simulating downhole environment)
- External surfaces of inhibited samples were wiped with inhibitor prior to immersion.
- Samples were immersed in Solution A (pH 2.7) and tested at ambient pressure with 100% H_2S in one chamber, and a separate test immersed samples in a high pressure chamber with 200psi (13.8 bar) H_2S partial pressure, 155psi (10.7 bar)CO_2, and a total pressure of 5000psi. (345 bar) at 25C.
- Samples were tested for 96 hours ~ 4 days.
- Upon completion of the immersion tests, samples were fatigue tested to failure to examine reduction in fatigue life, with and without inhibitors at 4,000 and 9,000 psi fatigue test pressure.

Why our testing methodology is more stringent

In light of the industry needs in the Middle East and around the world we conducted lab testing using the most stringent criteria allowable in a lab environment.

- Testing procedure utilized NACE Solution A with a pH of 2.7 followed by bending fatigue to examine CT performance.
- Higher Partial Pressures used than previously done by other manufacturers for full tube immersion followed by fatigue testing.
- CO_2 was used to accelerate corrosion reaction through oxygen content.
- Fatigue testing done at higher absolute “pumping pressures” than previously done.
- Ratio of sour fluid to exposed tube surface area was maximized by isolating extremities of the samples tested.

Testing Conclusions

Fatigue testing with inhibitors showed retention of fatigue life after 96 hours exposure. Both high and low pressure fatigue showed consistent fatigue results:

- Good fatigue performance (30-40% derating) without inhibition for DURACOIL 95.
- Better fatigue performance with inhibition.
- Always use inhibition in sour environments.

H_2S Testing Comparison **Between Manufacturers**

Ambient Testing Protocol with 100% H_2S			
SPE Paper	Presenting at ADIPEC 2025[1]	SPE-218332-MS	SPE-184796-MS
Company	**FET-Global Tubing**	**Manufacturer A**	**Manufacturer B**
Failure Mode Tested	SSC/HIC	SSC/HIC	SSC/HIC
NACE Test Solution	NACE Solution A 100% H_2S Full Tube Immersion +Fatigue	NACE Solution A 100% H_2S Full Tube Immersion +Fatigue	NACE Solution A 100% H_2S Full Tube Immersion +Fatigue
Material Grade	DURACOIL 95	Q&T 95	Q&T 95
Material Hardness	<= 26 HRC	<= 26 HRC	20 to 26 HRC
NACE Solution pH	2.7 (Solution A)	2.7 (Solution A)	2.7 (Solution A)
Partial Pressure H_2S	Ambient Pressure 14.5 psi (1 bar)	Ambient Pressure 14.5 psi (1 bar)	Ambient Pressure 14.5 psi (1 bar)
Partial Pressure CO_2	None	None	None
Total Test Pressure	14.7 psi (1 bar)	14.7 psi (1bar)	14.7 psi (1 bar)
Exposure Time	96 hours (4 days)	96 hours (4 days)	96 hours (4 days)
Temperature	75°F ±5	75°F ±5	75°F ±5
Number of Environments Tested	1 environment. Non-inhibited	1 environment. Non-inhibited	1 environment. Non-inhibited
Hoop Stress % of SMYS[4] (during fatigue)	Low Pressure 15%	Not Tested	Low Pressure 10%
	High Pressure 35%	High Pressure 42%	High Pressure 30%
Bending Strain (during fatigue)	1.4%	1.4%	2.4% Maximum
Inhibitor Used	None	None	None
Inhibitor concentration	None	None	None
Age of Coupons for Testing	Newly Milled Pipe	Newly Milled Pipe	Newly Milled Pipe
Samples Tested	Base, Bias Weld and Seam Weld	Base, Bias Weld and Seam Weld	Base, Bias Weld and Seam Weld
Remaining Fatigue Life After Sour Exposure	Low Pressure 61%	Not Tested	Low Pressure 50%
	High Pressure 75%	High Pressure 68%	High Pressure 70%

DURACOIL 95 showed better fatigue performance in severe sour environments than conventional GT-90, retaining 70% of its sweet life. Bias Welds require no derating in sour service, consistent with past research.

Competitor A's results aligned with previous studies (SPE-184796-MS), maintaining 68% of sweet life at 42% hoop stress

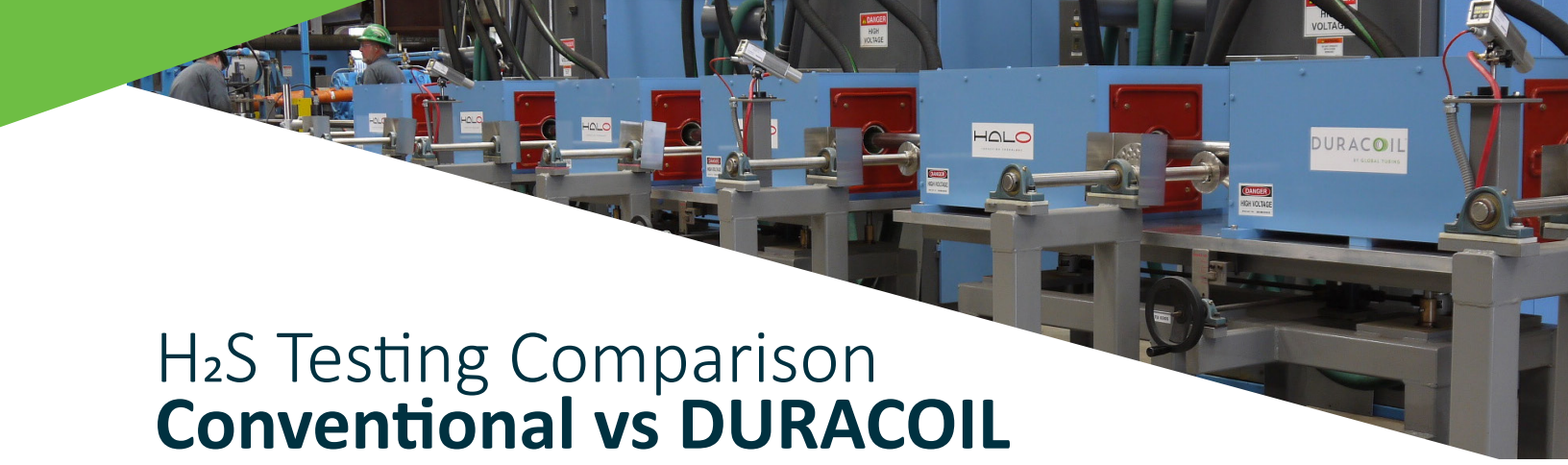
Competitor B's tests without inhibition showed 50% fatigue life remaining at lower CT circulating pressures and 70% at higher pressures compared to non-sour life.

H_2S Testing Comparison
Between Manufacturers

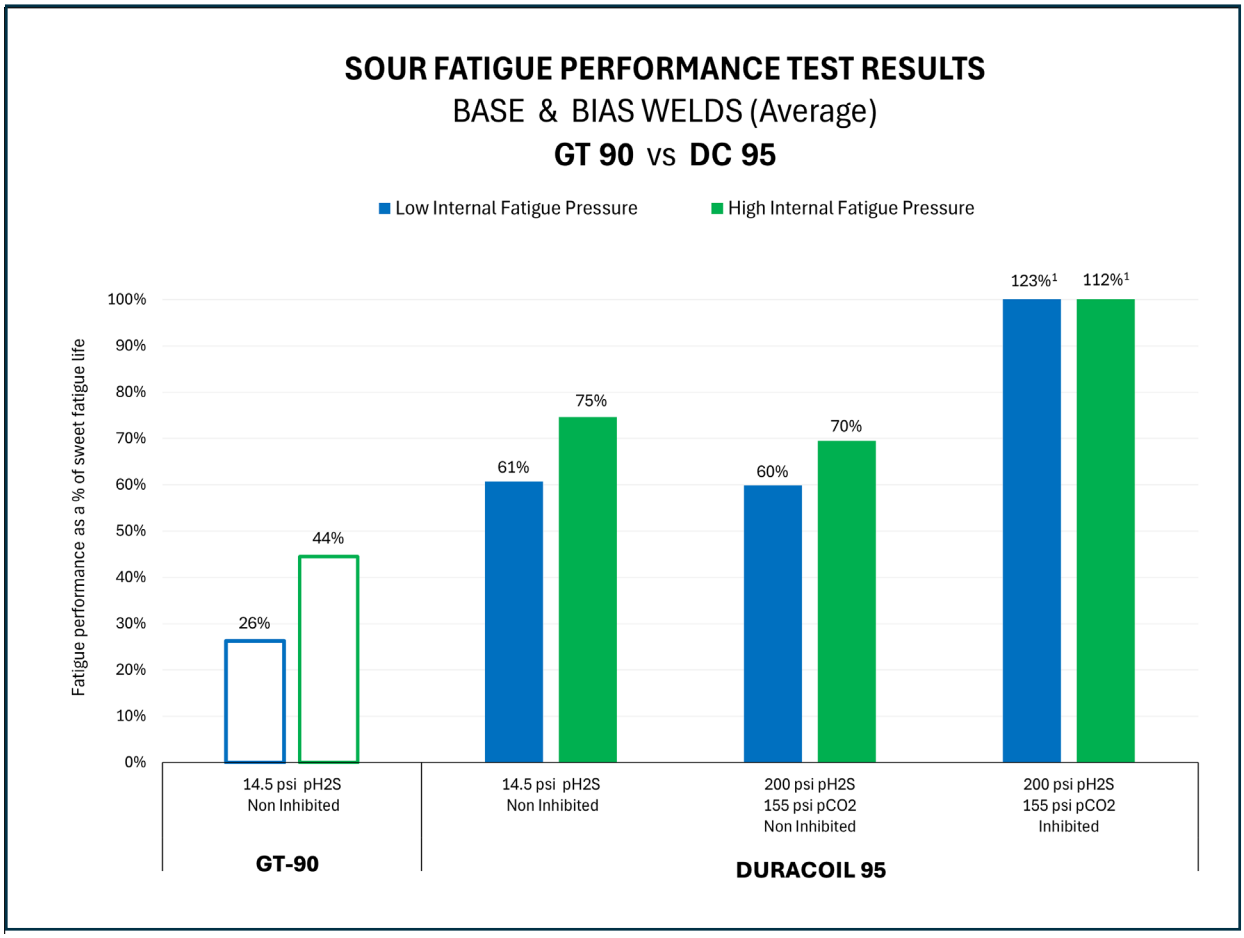
High pressure testing protocol with 200 psi partial pressure H_2S and 155 psi partial pressure CO_2			
SPE Paper		Presenting at ADIPEC 2025[1]	Abu Dhabi ICoTA Round Table 2022[2] Canada ICoTA Round Table 2022[3]
Company		**FET-Global Tubing**	**Manufacturer B**
Failure Mode Tested		SSC/HIC	SSC/HIC
NACE Test Environment		NACE Solution A 100% H_2S Full Tube Immersion +Fatigue	NACE Solution A 100% H_2S Full Tube Immersion +Fatigue
Material Grade		DURACOIL 95	Q&T 95
Material Hardness		<= 26 HRC	<= 26 HRC
NACE Solution pH		2.7 (Solution A)	2.7 (Solution A)
Partial Pressure H_2S		High Pressure 4%, 200 psi (13.8 bar)	High Pressure 2- 4%, 126-200 psi (8.7- 13.8 bar)"
Partial Pressure CO_2		3.1%, 155 psi (10.7 bar)	3.1%, 155 psi (10.7 bar)
Total Test Pressure for Exposure		5,000 psi (344.7 bar)	5,000 psi (344.7 bar)
Exposure Time		96 hours (4 days)	96 hours (4 days)
Temperature		75°F ±5	75°F ±5
Environments Tested		1 environment. Inhibited and non-inhibited	1 environment. Inhibited and non-inhibited
Hoop Stress % of SMYS[4] (during fatigue)		Low Pressure 15%	Not Published
		High Pressure 35%	Not Published
Bending Strain (during fatigue)		1.4%	Not Published
Inhibitor Used		Petroleum Distillate	Yes, But Not Published
Inhibitor concentration		Thin layer applied to simulate lubricator	Not Published
Age of Coupons for Testing		Newly Milled Pipe	Newly Milled Pipe
Samples Tested		Base, Bias Weld, and Seam Weld	Base, Bias Weld and Seam Weld
Remaining Fatigue Life After Sour Exposure	**Non-inhibited**	Low Pressure 60%	Low Pressure 65%[5]
		High Pressure 70%	High Pressure 90%[5]
	Inhibited	Low Pressure 123%	Low Pressure 80%[5]
		High Pressure 112%	High Pressure 90%[5]

For DURACOIL 95, 100% of fatigue life remains after sour immersion with inhibition, and 60-70% without inhibition compared to sweet life and is consistent with other published data. Competitor B's product shows similar fatigue life after sour immersion, regardless of inhibition.

1. Findings to be presented at the ADIPEC 2025 Exhibition and Conference, 3-6 November, 2025 in Abu Dhabi, UAE
2. Presented at the SPE/ICoTA Workshop: Extreme Well Intervention - Advanced Rigless Strategies and Solutions, held May 24–25, 2022 in Abu Dhabi, UAE
3. Presented at the 2022 ICoTA Canada Roundtable, held November 2, 2022 in Calgary, AB
4. SMYS - Specified Material Yield Strength
5. Results are the average of presented results



H_2S Testing Comparison
Conventional vs DURACOIL



When GT-90 conventional Coiled Tubing is compared to DURACOIL 95 at ambient conditions, DURACOIL 95 shows better performance. Additionally, the remaining fatigue life of DURACOIL 95 after exposure to high partial pressures of H2S, with and without inhibitors, continues to demonstrate superior results in comparison to GT-90.

1. Samples exposed to H_2S have been shown to exceed sweet life fatigue in laboratory testing. Possible causes for this are included in SPE paper 218327 and are part of the current developments in fracture mechanics. In all sour environments, FET-Global Tubing recommends using inhibitors with coiled tubing.

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