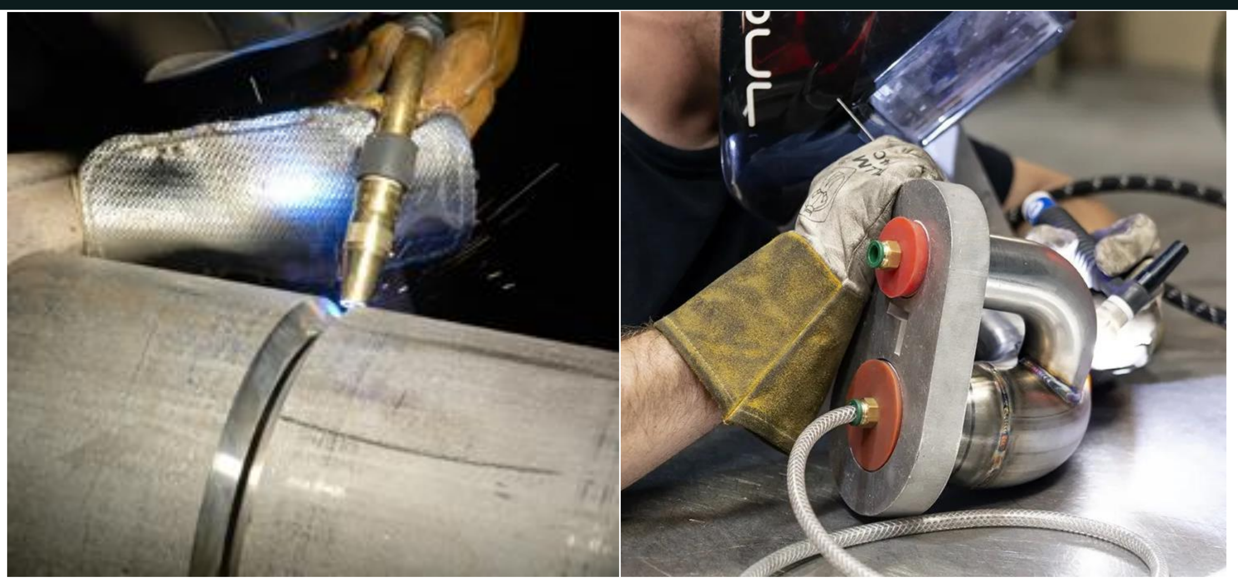
No Backing Gas (NBG) Welding of Austenitic Stainless Steels

Richard Li, The Ohio State University

Carolin Fink (OSU), Jorge Penso (Shell), Dustin Wagner (Miller), Atsushi Takahashi (JGC), Brandon Rollins (DNV)

Background and Motivation

- Backing gas is typically used in open-gap root welding of austenitic stainless steels to protect from atmospheric contamination, oxidation, and loss of alloying elements. However, purging can be costly or impractical due to access restrictions, personnel safety, or economic factors.
- No-backing gas (NBG) GMAW technology developed about 20 years ago and successfully used for stainless steel piping in power, oil and gas and liquid nitrogen gas (LNG) industry; increase in safety and productivity.
- Last 5 years have seen multiple studies that GMAW-NBG welding can produce welds with corrosion resistance akin to that produced by GTAW process with argon backing gas.
- However, there is a need to validate the use of no-backing gas technology in corrosive environments, such as chlorine or amine environments.



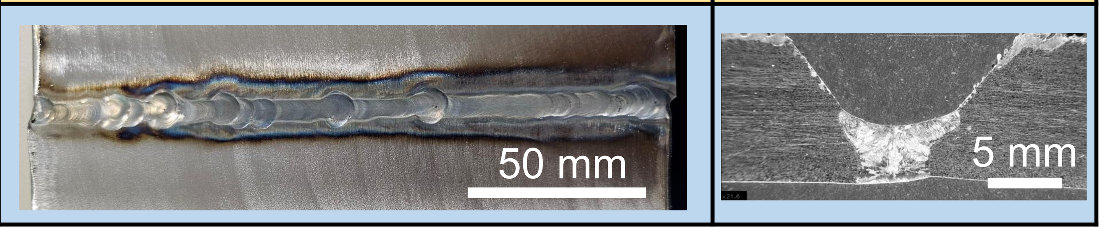
Images of welding stainless steel piping using GMAW and GTAW processes with back purging (Source: Miller Electric)

Experimental Approach & Results

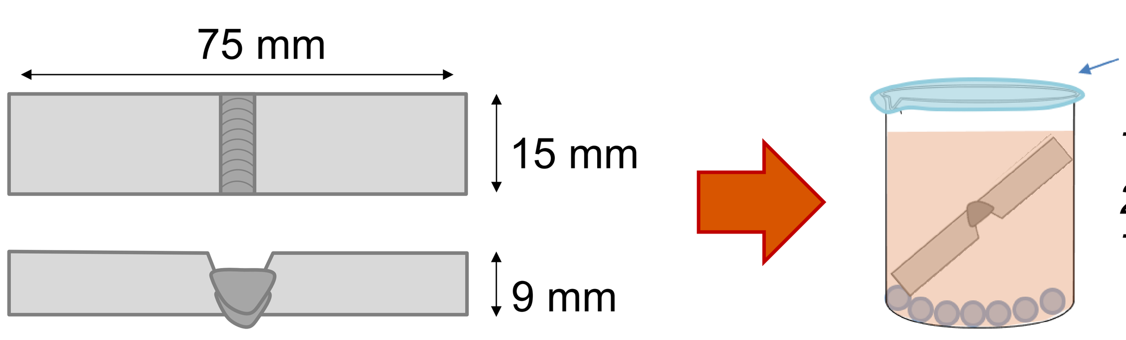
Weld Test Matrix

Condition	BM	FM	Process	Shielding Gas	Backing
1	316/316L	ER316LSi	GTAW (filled)	100% Ar	NBG
2	304/304L		SC-GMAW (root pass) P-GMAW (hot pass)	98%Ar-2%CO2	
3			SC-GMAW (root pass) P-GMAW (hot pass)	90%He-7.5%Ar-2.5%CO2 (root pass), 98%Ar-2%CO2 (hot pass)	
4 (baseline)			GTAW (root + hot pass)	100% Ar	100% Ar

Weld test matrix for GTAW and GMAW no backing gas (NBG) welds and baseline weld. Corresponding pictures of the root appearance and macrograph cross-sections are shown in the figure on the right.

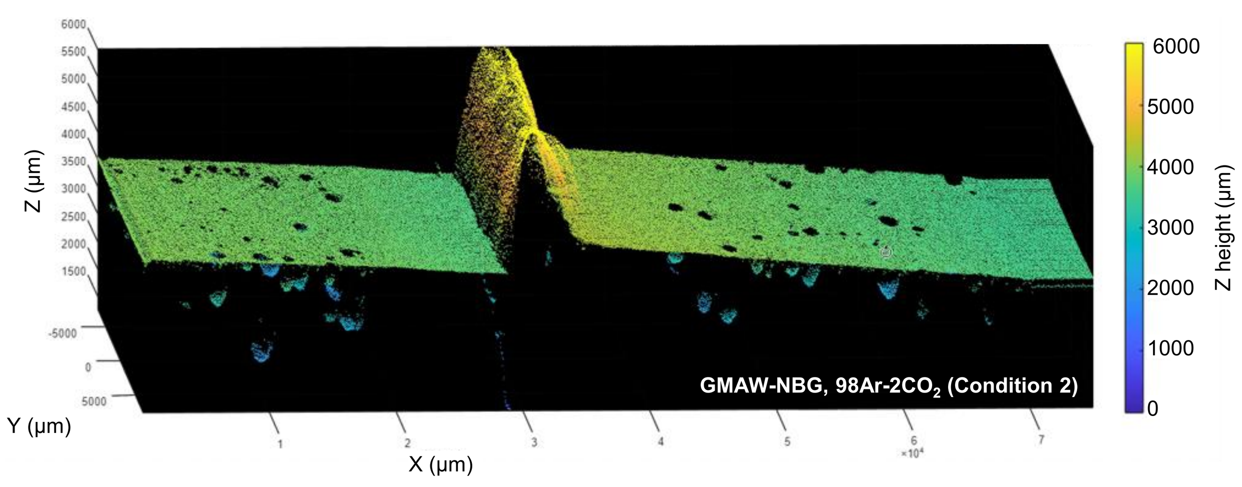
Condition	Root Appearance	Macrograph
1		
2		
3		
4		

Ferric Chloride Immersion Test (ASTM G48)

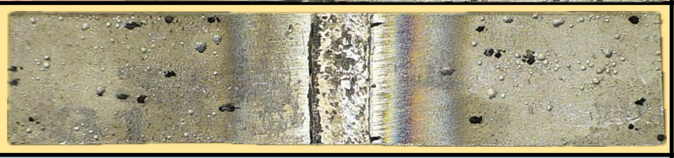
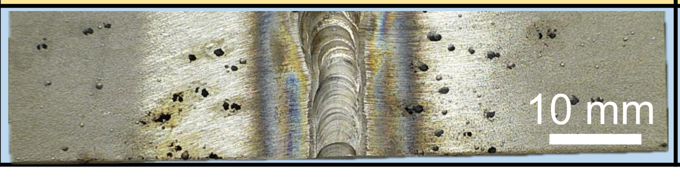


Temperature Controlled: 22°C ± 2°C
Time: 72hrs

Specimen geometry; 3 specimens tested per condition



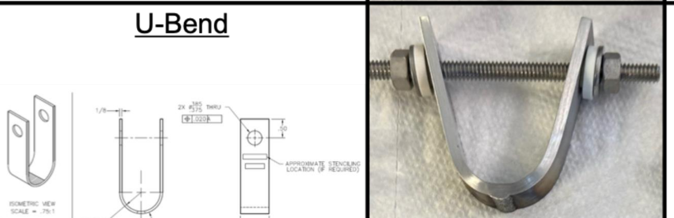
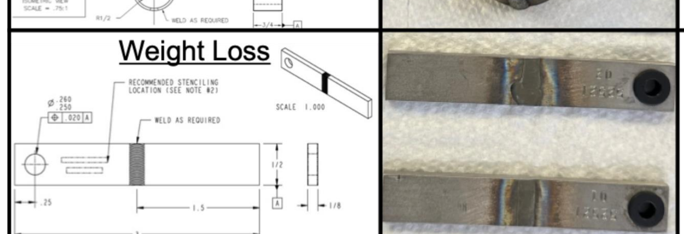
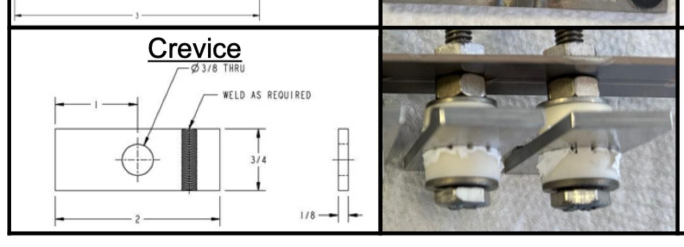
Pit depth quantified using optical coherence tomography system (IPG Photonics LDD-700)

Condition	Weight Loss Sample	Average Corrosion Rate (g/(m²*h))	Average Pit Depth (mm)
1		5.5	1.7
2		4.9	1.0
3		4.9	1.1
4		5.3	1.2

Weight loss specimens after ferric chloride immersion; note difference in base metal for GTAW-NBG weld (Condition 1) with pits primarily at weld toe and in weld metal.

Corrosion rates and pitting was comparable for GMAW-NBG and GTAW baseline weld.

Amine Solution Corrosion Test

Corrosion Test Type	Picture	ASTM Standard
U-Bend 		G30, G48
Weight Loss 		G1, G31
Crevice 		G78

3 specimens tested per test type and weld condition

Autoclave setup for amine corrosion test at DNV

	CO_2 (mg/L)	H_2S (mg/L)	pH
Amine solution	11,688.932	12,013.664	9.87 @ 22.7 °C

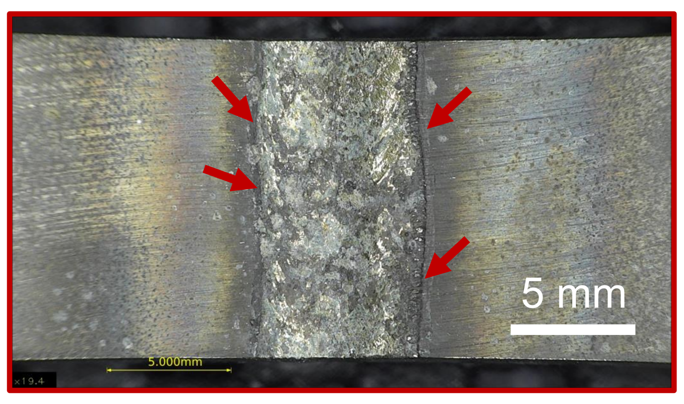
Analysis of amine solution from refinery

Purge gas	Temperature	Staring pressure	Test Time
H_2S: 2.6 mol%, CO_2: 1.8 mol%, N_2: Bal.	225 °F	@ 65 psi	30 days

Test conditions

Condition	Weight Loss Samples (After Corrosion Test)
1	
2	
3	
4	

Weight loss specimens after amine corrosion tests



Shallow pitting along weld toe in He tri-mix shielding gas GMAW-NBG weld (Condition 3); likely caused by higher Cr depletion and larger oxide particles due to higher temperature arc from He

Condition	Weight Loss: Average Corrosion Rate (g/(m²*h))	Crevice Corrosion: Average Corrosion Penetration (um)	U-bend: Cracking Observed?
1	0.003	<20	No
2	0.003	<20	No
3	0.007	<20	No
4	0.003	<20	No

None of the welds experienced significant corrosion in amine solution.

Conclusions

- In Cl- environment, corrosion behavior of GMAW-NBG welds comparable to conventional GTAW weld with argon purging; GTAW-NBG weld on Type 316L SS also achieved similar corrosion rates (but pits primarily at weld toe and in weld metal).
- Comparable behavior was also observed in amine environment: no significant crevice corrosion and no cracking in U-bend specimens; only exception was higher weight loss in GMAW-NBG weld with high-He shielding related to shallow pitting along weld toe (hotter arc with He, potentially more Cr depletion at weld toe).

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