



Corrosion behaviour of weld stainless steels in stagnant LBE

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Weld materials: : Objective

- ✓ Objective: Study of the influence of welded on the protective characteristics of AISI 316L and T91 steel in LBE.
- ✓ This study have been performed in the frame of the FP6-IP-EUROTRANSDOMETRA Project, No: FI6W-CT-2004-516520, task 4.2.1 "*Long term corrosion kinetics, corrosion kinetics model and high temperature corrosion barriers development and characterisation*"

Test matrix: weld

✓ Two materials tested: plates of T91/T91 and 316L/T91

✓ Tests: 500°C

		H ₂ /H ₂ O=0,03 [O]=4 10 ⁻⁶ %wt	H ₂ /H ₂ O=3 [O]=4 10 ⁻⁸ %wt
Time (h)	500	Ok	Ok
	2000	Ok	Ok

✓ Tests: 550°C

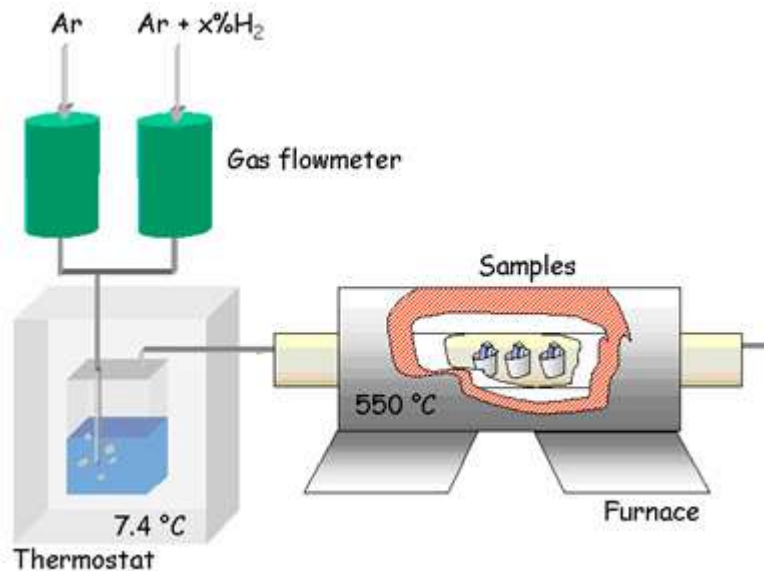
		H ₂ /H ₂ O=0,03 [O]=1.4 10 ⁻⁶ %wt	H ₂ /H ₂ O=3 [O]=1.4 10 ⁻⁷ %wt
Time (h)	500	Ok	Ok
	2000	Ok	Ok

✓ Tests will be carried out at 500 and 550°C for 500 and 2000 hours with two different H₂/H₂O ratios: 0.03 and 3

✓ Oxygen concentrations of the matrix were calculated

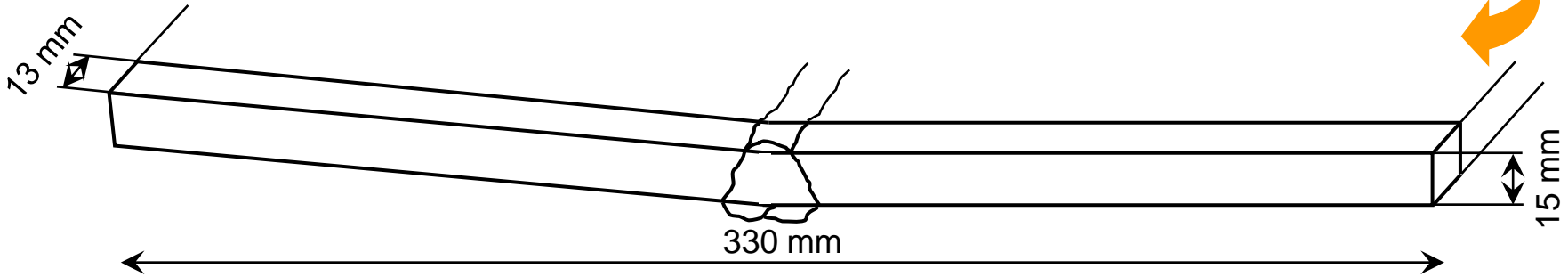
Device used for static corrosion tests

- ✓ OCS: H_2/H_2O equilibrium
- ✓ Oxygen activity calculated

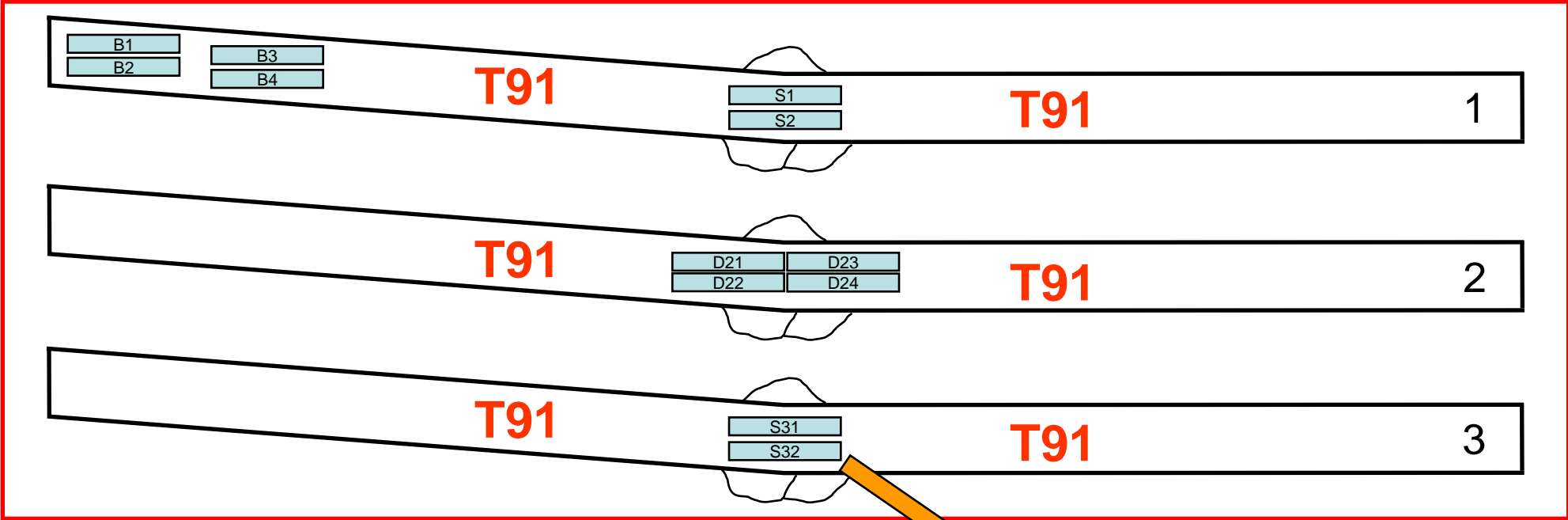


- ✓ Longitudinal sections of the specimens were prepared without removing the adhering LBE
- ✓ All specimens were analysed by optical microscopy and Scanning Electron Microscopy (SEM-EDX)

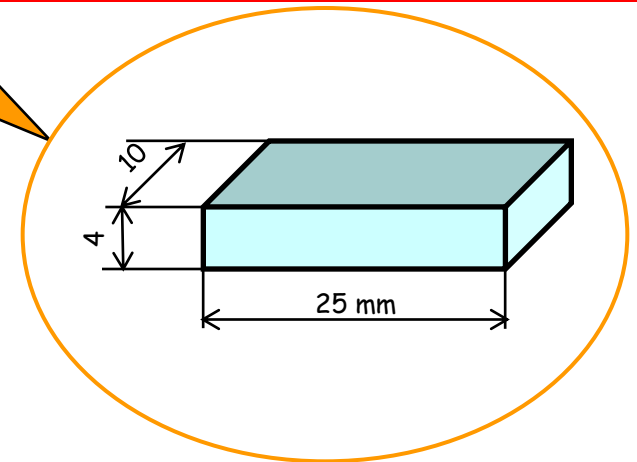
Influence of weld, T91/T91 and 316L/T91



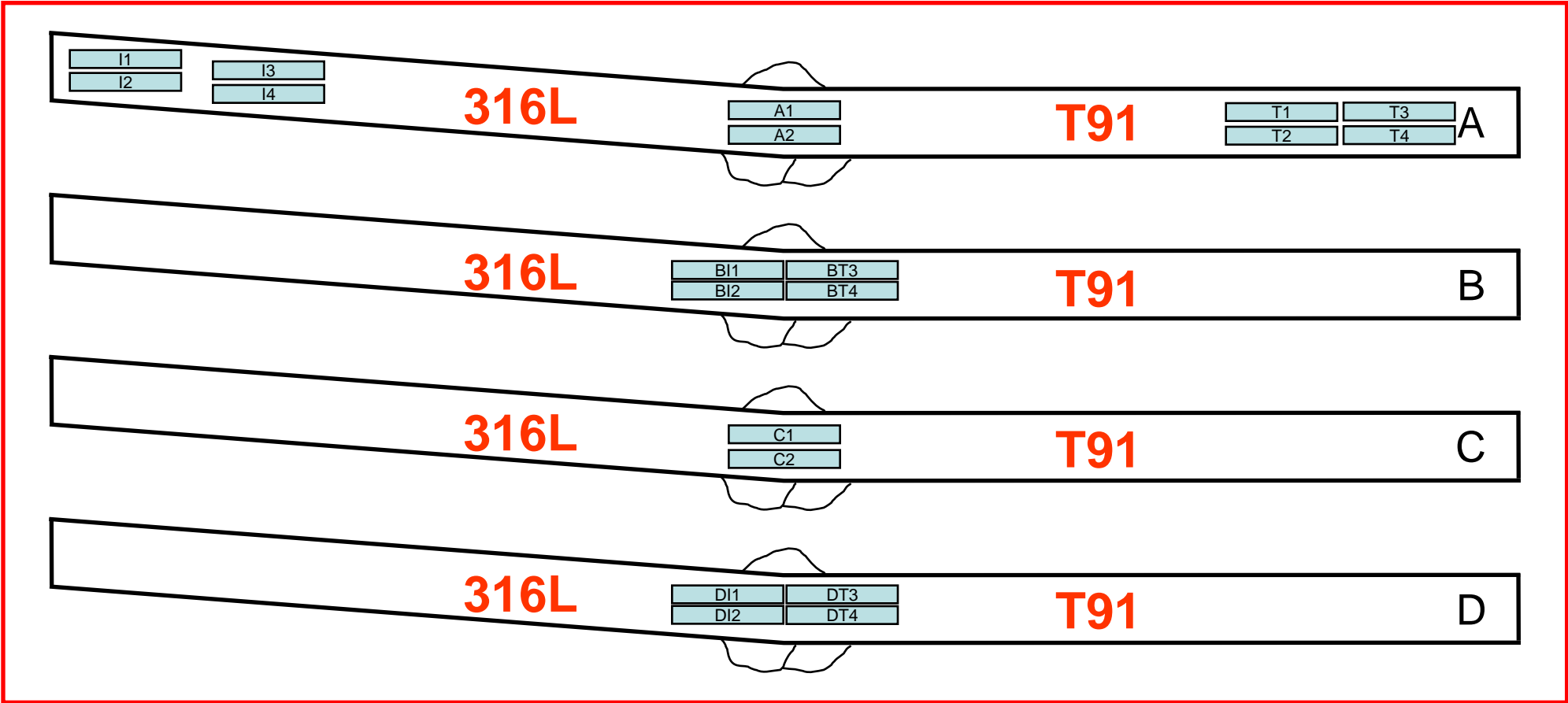
Influence of weld, T91/T91



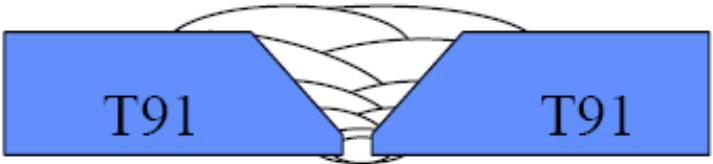
- ✓ Specimens from three zones:
 - Welding area
 - Heat affected zone (HAZ)
 - Bulk



Influence of weld, 316L/T91



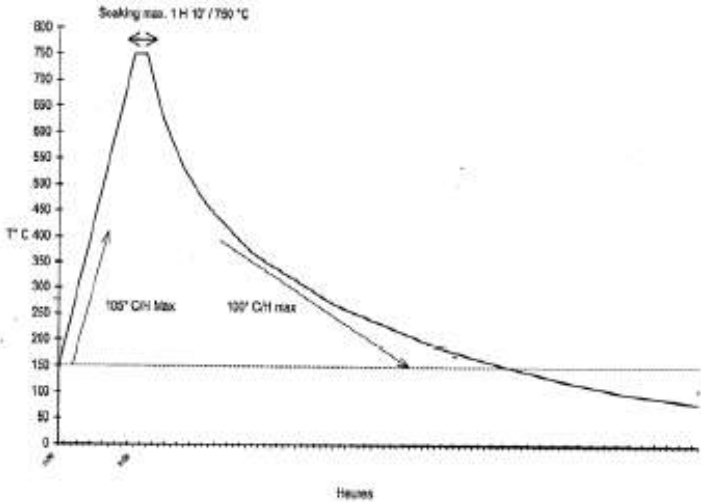
Procedure of weld: T91/T91



- ❖ Used techniques: G.T.A.W. (Gas Tungsten Arc Welding or TIG), S.M.A.W. (Shielded Metal Arc Welding), S.A.W. (Submerged Arc Welding)

- ❖ 10 passes: 1, 2: GTAW, electrode Chromo 9V, Ø2,5-3,2-4, preheated >220 C
 3-6 : SMAW, electrode ThermanMTS3, Ø2,4, preheated >220 C
 7-10:SAW, electrode UP MTS3, Ø2,5,preheated >230 C
 flux: Marathon 543

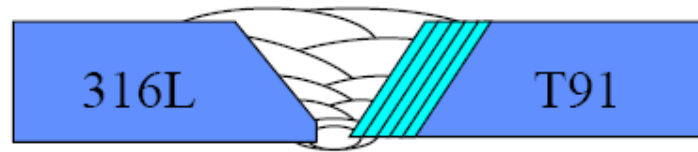
- ❖ Heat treatment: starting temperature: 140 C
 heating rate: Max.105 C/h
 soaking Max. 1h10min at 750 C
 cooling rate: Max. 100 C/h
 finishing temperature: 80 C



References:

- Van den Bosch et al. "BM & welds characterization". EUROTRANS_DM4 DEMETRA Monitoring meeting. May 16-17, 2006, Karlsruhe, Germany.
- J. Van den Bosch et al., "Procurement and characterisation of T91 and SS316L plates", R4197 (2005)
- J. Van den Bosch et al., "Characterization of TIG and EB weldments of T91 and 316L", R4399 (2006)

Procedure of weld: 316L/T91



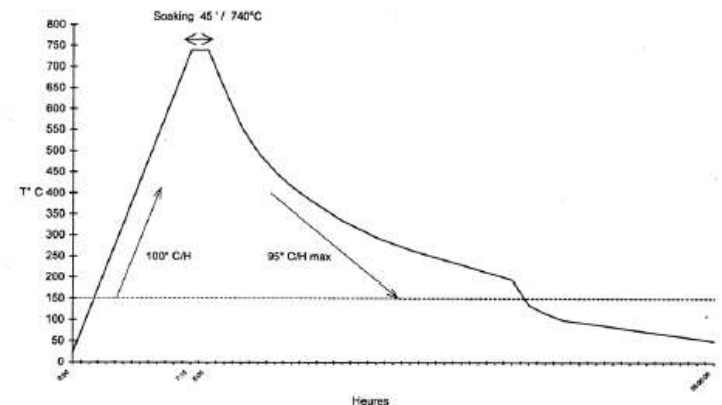
❖ Used techniques:

- For filling: S.M.A.W.
- For welding: G.T.A.W. and S.M.A.W.

❖ 5 passes for filling using SMAW, electrode Arosta309S, Ø2,5-3,2; preheated >250 C

❖ Welding in 11 passes: 1-2: GTAW, filLNT 316L Ø2,4; NortalInox20-10-5, Ø2,4, AQ 8447
 3-11: SMAW, electrode Arosta316L, Ø2,5-3,2

❖ Heat treatment: starting temperature: 25 C
 heating rate: 100 C/h
 soaking Max. 45min at 740 C
 cooling rate: Max. 95 C/h
 finishing temperature: 50 C

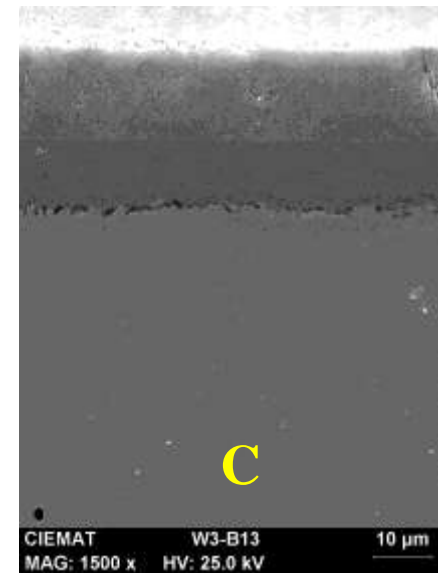
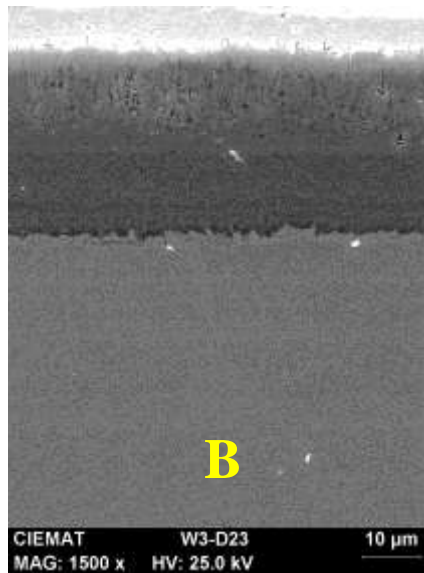
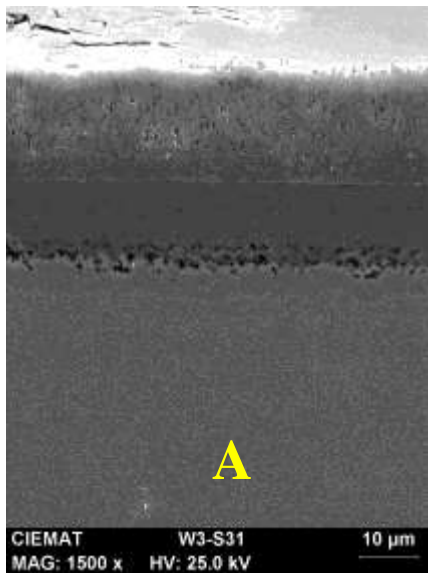
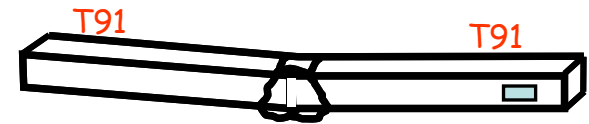
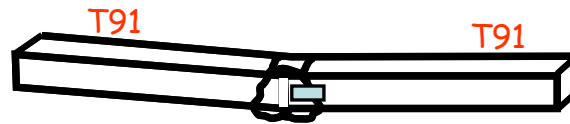


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- Van den Bosch et al. "BM & welds characterization". EUROTRANS_DM4 DEMETRA Monitoring meeting. May 16-17, 2006, Karlsruhe, Germany.
- J. Van den Bosch et al., "Procurement and characterisation of T91 and SS316L plates", R4197 (2005)
- J. Van den Bosch et al., "Characterization of TIG and EB weldments of T91 and 316L", R4399 (2006)

Results of tests: T91 - T91 weld

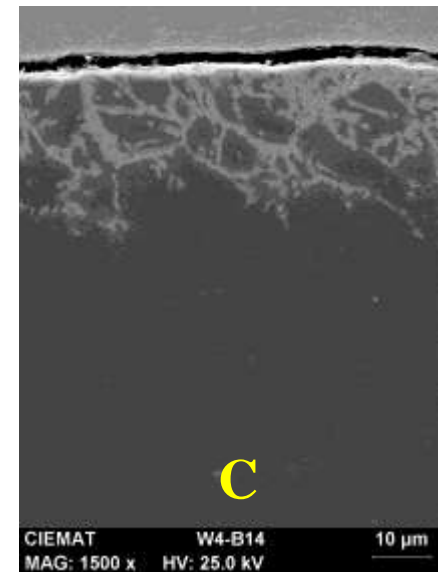
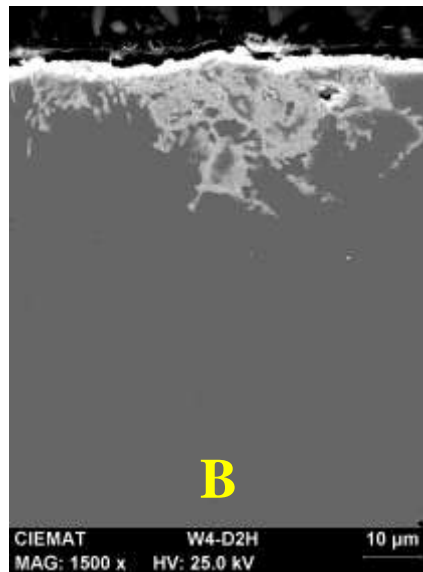
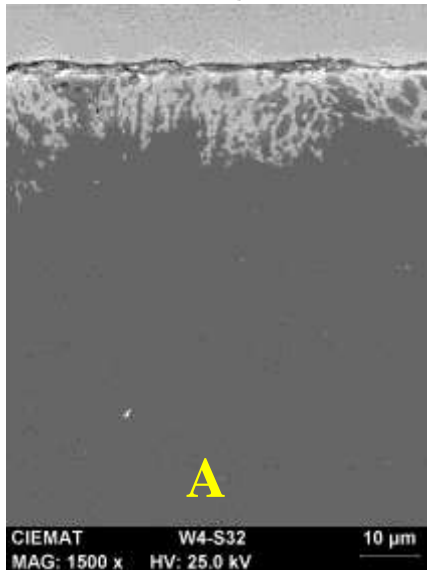
500°C - 2000h - H₂/H₂O=0.03



- ✓ In general, good behaviour for all conditions testing
- ✓ Double oxide layers up to 30 μm at 500°C for 2000 h under oxidant atmosphere.
- ✓ No differences between welded and bulk areas
- ✓ Similar result were found in the cases of specimens tested at 550°C, with ticker oxide layers (up to 50 μm after 2000 hours) but similar morphologies.

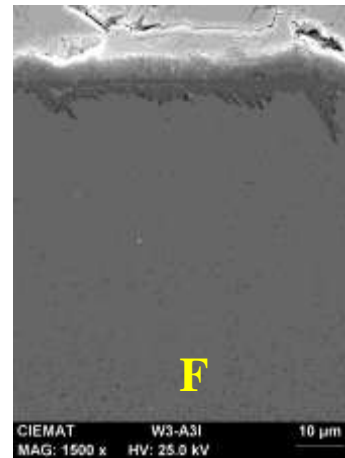
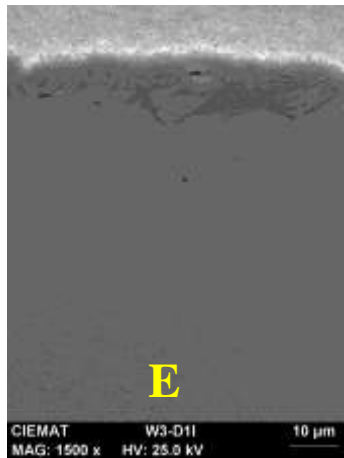
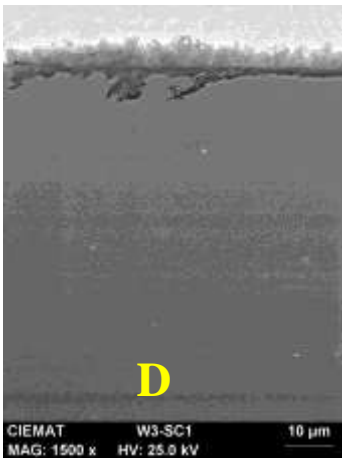
Results of tests: T91 - T91 weld

500°C - 2000h - H₂/H₂O=0.03

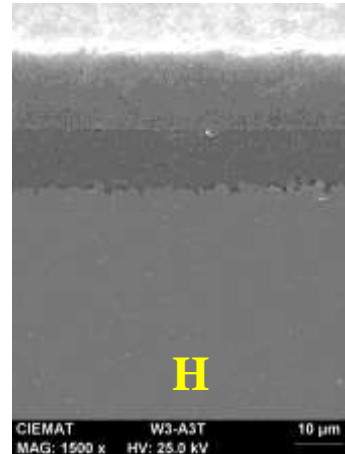
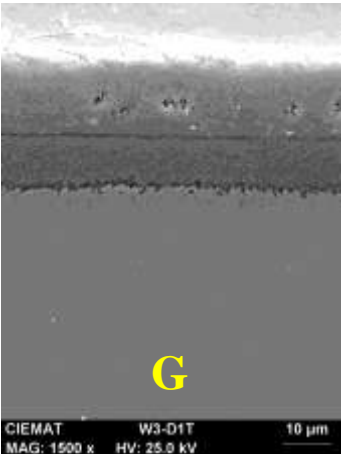


- ✓ In general, the specimens present a light process of dissolution. The thickness of the corrosion layer became 20 μm in depth for 2000 h.
- ✓ The weld joint (specimens A and B), present a similar result that the bulk materials (C). No differences between welded and bulk areas
- ✓ Similar result were found in the cases of specimens tested at 550°C.

Results of tests: 316L - T91 weld



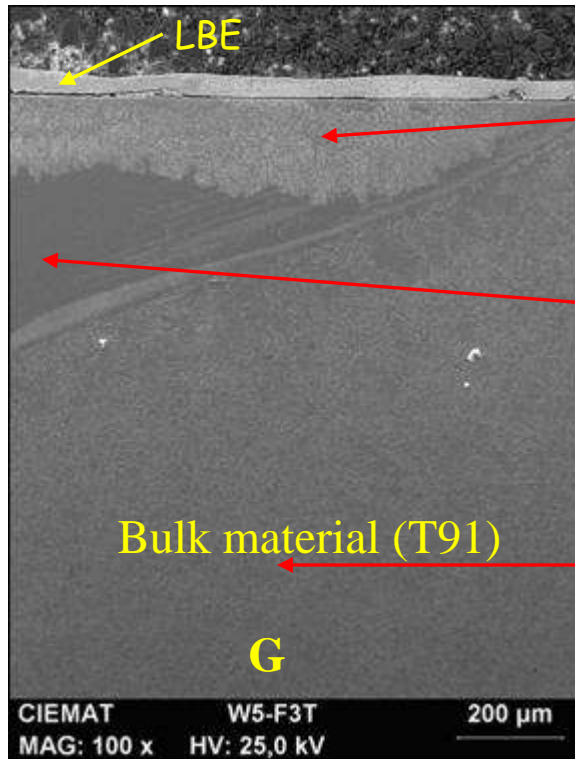
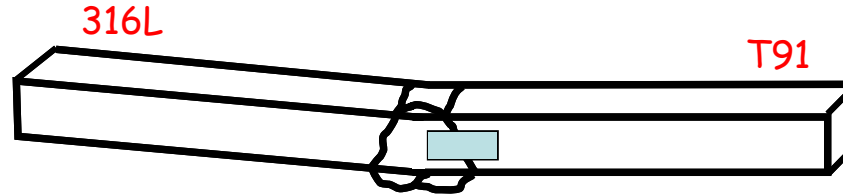
500°C
2000h
H₂/H₂O=0.03



- ✓ Adherent and compact oxide layers are presented in all specimens.
- ✓ D, E and F (mainly probes of 316L): outer layers of Fe-O and inner layers of Fe-Cr-Ni-O. No differences in thickness or morphology have been detected.
- ✓ G and H (mainly probes of T91): thickness of the oxide layers are 30 μm after 2000 h. This result is similar to that presented above for the specimens of T91-T91 welded joint.

Results of tests: 316L - T91 weld

550°C
2000 h
 $H_2/H_2O = 0.03$



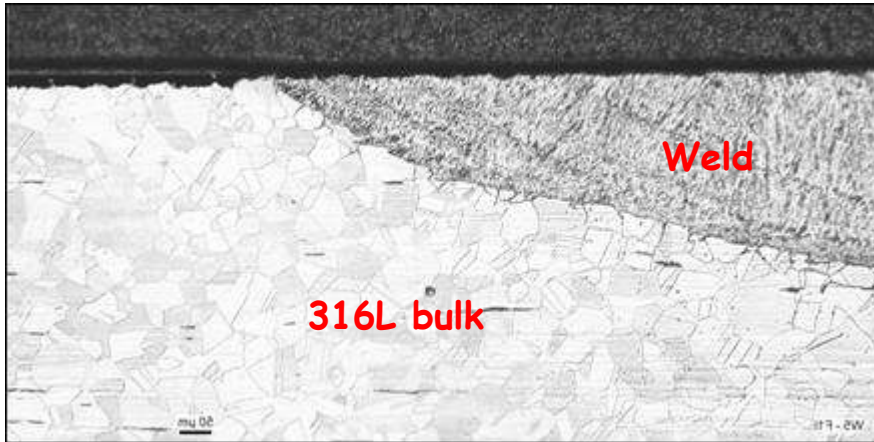
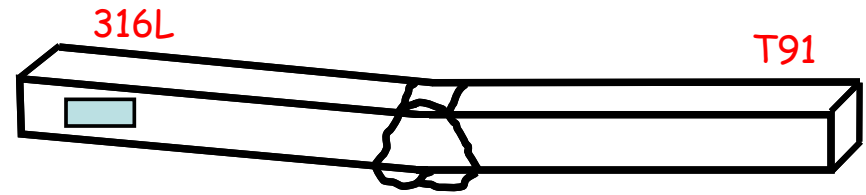
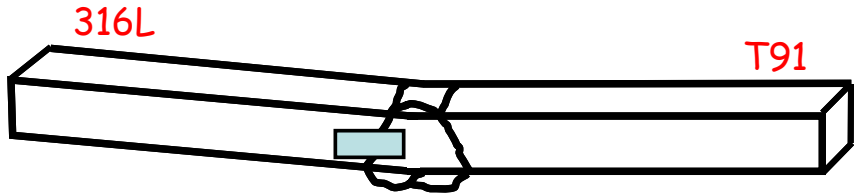
	Fe	Cr	Ni	V	Si
wt%	52,25	22,97	0,91	---	0,66

	Fe	Cr	Ni	V	Si
wt%	70,76	21,30	7,62	---	0,32

	Fe	Cr	Ni	V	Si
wt%	89,48	9,55	--	0,68	0,04

- ✓ Dissolution on welds (approx. 200 μm).
Typical depletion of Ni
- ✓ Dissolution has not been detected on T91 area immerse in LBE

Welding tests: 316L - T91

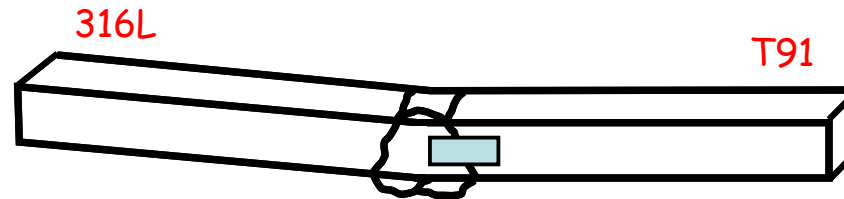


550°C - 2000 h; $H_2/H_2O = 0.03$

550°C - 2000 h; $H_2/H_2O = 0.03$

- ✓ General behaviour: no dissolution
- ✓ Similar behaviour was observed for the tests at 500°C


Welding test: 316L - T91



550°C - 2000 h; $H_2/H_2O = 3$

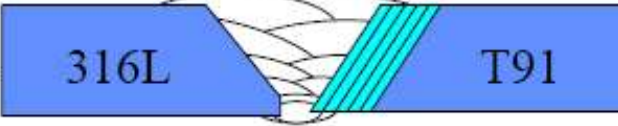
- ✓ Dissolution on welds up to 300 μm
- ✓ This effect has not been observed for the tests at 500°C

Welding test: discussion

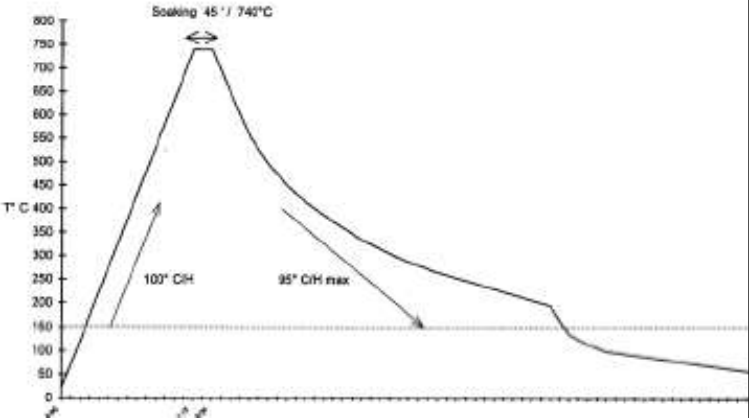


STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

T91/316L weld



- Used Techniques:
 - For filling (beurrage): S.M.A.W.
 - For welding: G.T.A.W. and S.M.A.W.
- 5 passes for filling using SMAW, electrode Arosta 309S, Ø2,5-3,2; preheated >250°C
- Welding in 11 passes: 1-2: GTAW, fil LNT 316L Ø2,4; Nortal Inox 20-10-5, Ø 2,4 AQ 8447
 3-11: SMAW, electrode Arosta 316L, Ø2,5-3,2
- Heat treatment after filling:



- Electrode Arosta 309S
- Special for weld dissimilar metals (mild and low alloyed steel to CrNi or CrNiMo stainless steel)
- Chemical composition (wt%):
 23.5 Cr, 12.5 Ni,
 0.020 C, 0.8 Mn, 0.80 Si

BM & welds characterization. J. Van den Bosch, A. Almazouzi. Karlsruhe meeting, 18/05/2006

General conclusions

- T91-T91 welded joints show the same corrosion properties as the parent materials for the conditions tested:
 - Thicker oxide layers under oxidant atmosphere
 - General dissolution under reductive atmosphere

- 316L-T91 welded joints, present an important dissolution over seam area at 550°C for both atmosphere that it is due to the electrode 309S used for the fabrication process.
 - This effect has not been observed for the tests at 500°C