

***ETGPA discussion on  
Material Selection  
and when to use Martensitic  
13 Chrome Stainless Steels***

**Nov. 2009**

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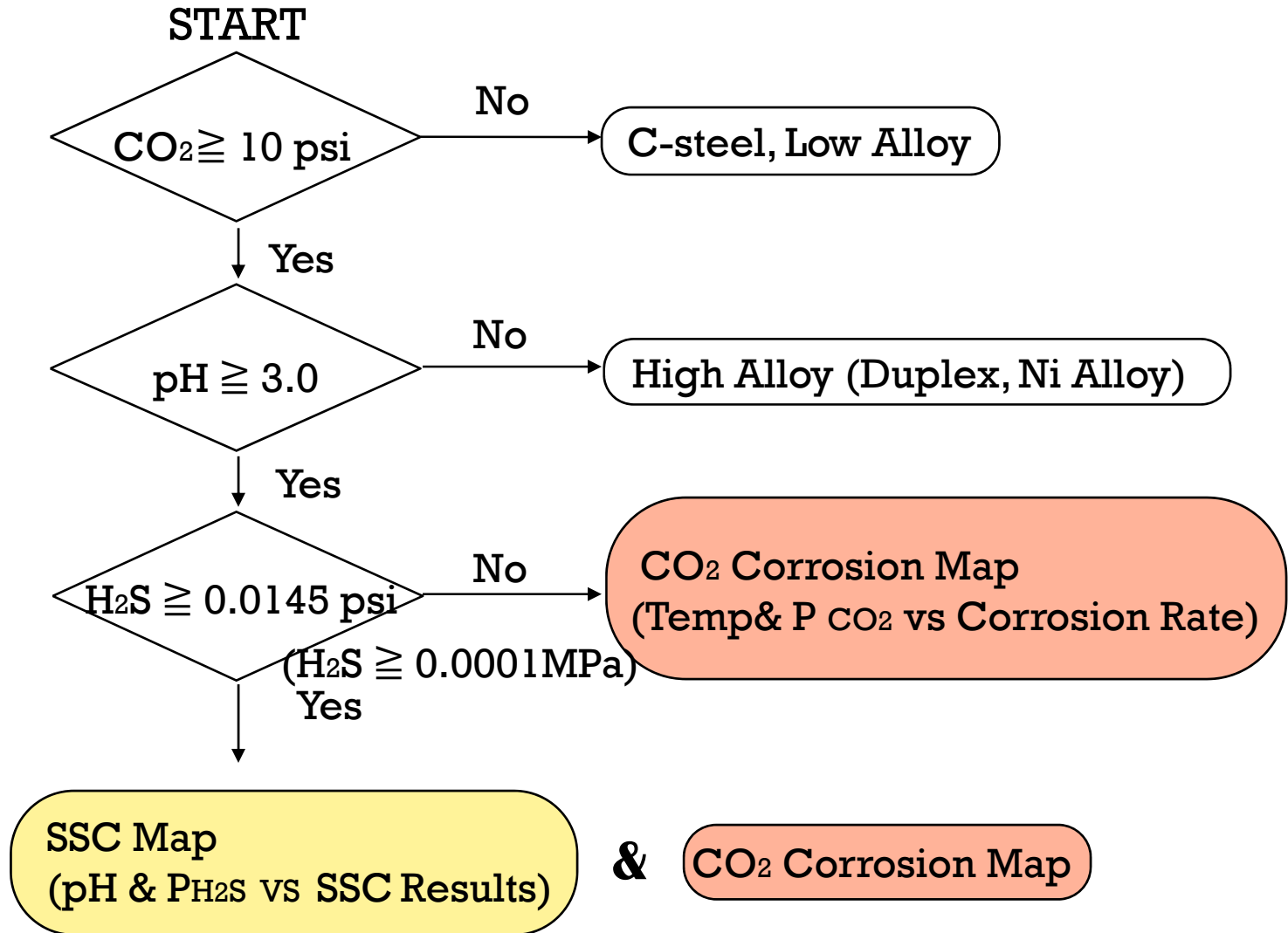
# Haynesville Play Conditions

- 2%-5% CO<sub>2</sub>
- 10-20 PPM H<sub>2</sub>S
- BHP 15,000 PSI – 1,000 PSI
- BHT 200 F - 400 F
- Chlorides 10,000 PPM 100,000 PPM
- Bicarb 200 PPM – 500 PPM

# Haynesville Play Conditions

- PPCO<sub>2</sub> 20 PSI - 750 PSI
- PPH<sub>2</sub>S 0.01 PSI – 0.3 PSI
- Estimated pH by Socrates 3.7 – 5.5
- NACE Notes Sour Environment to be .05 PSI and higher.
- Industry Standard for Corrosion with CO<sub>2</sub> present is 10 PSI and higher

# Material Selection Chart

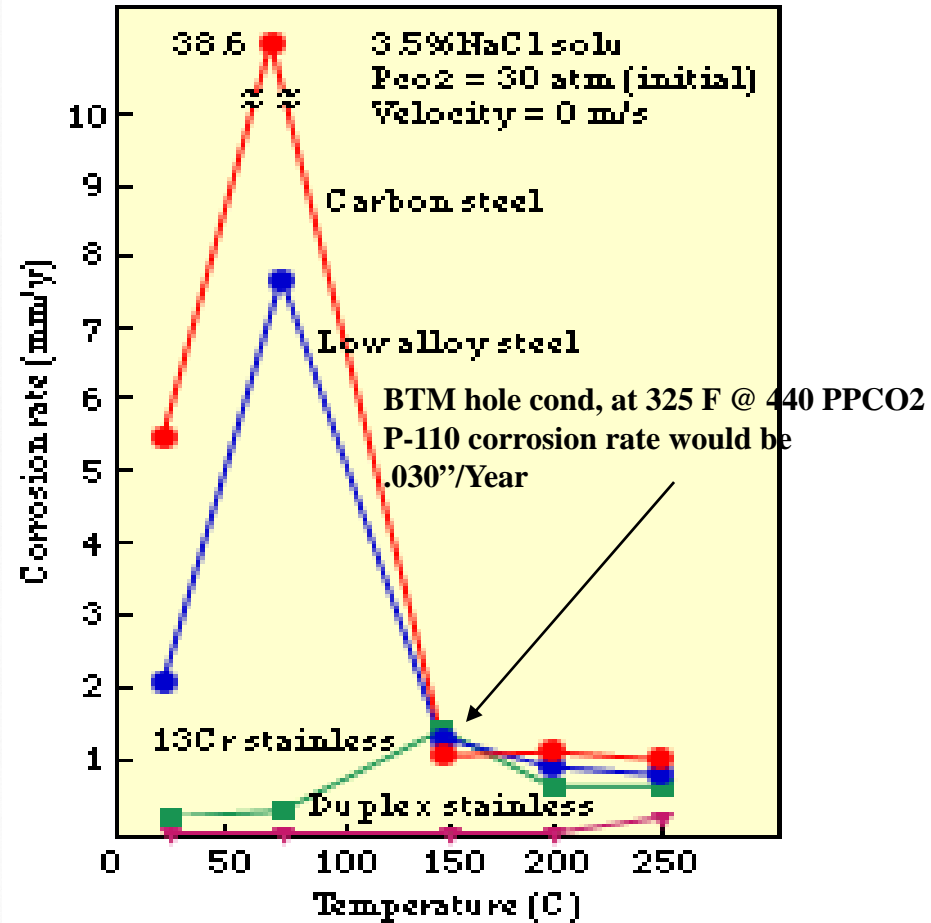
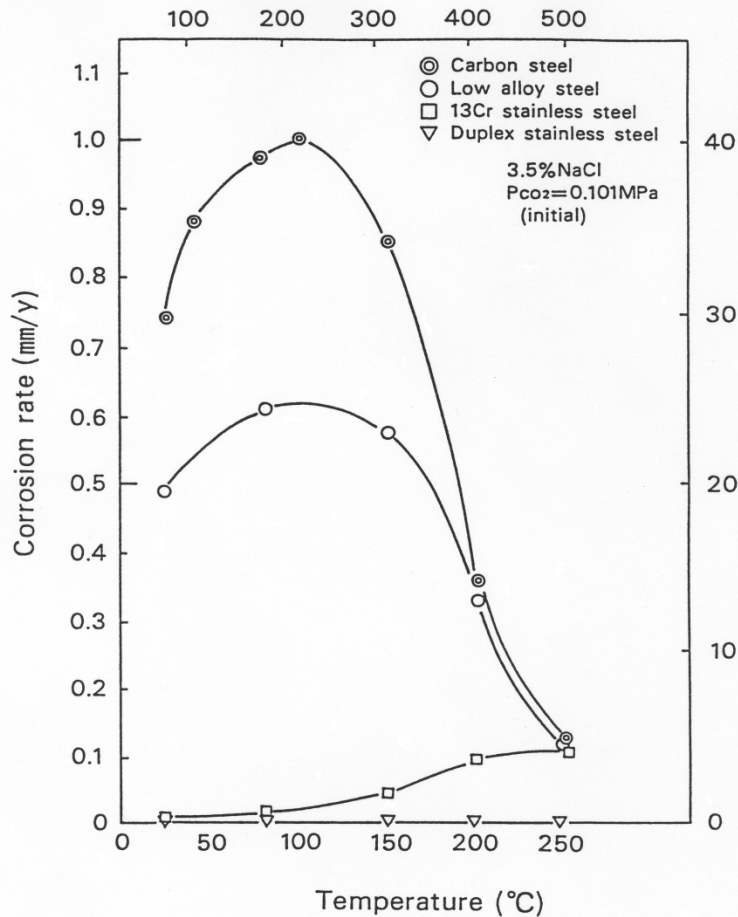


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PPCO2	120psi
PPH2S	0.44psi
pH	4.6
Cl-	175,000ppm
Buffering/pH Control	CH3COONa/CH3C OOH

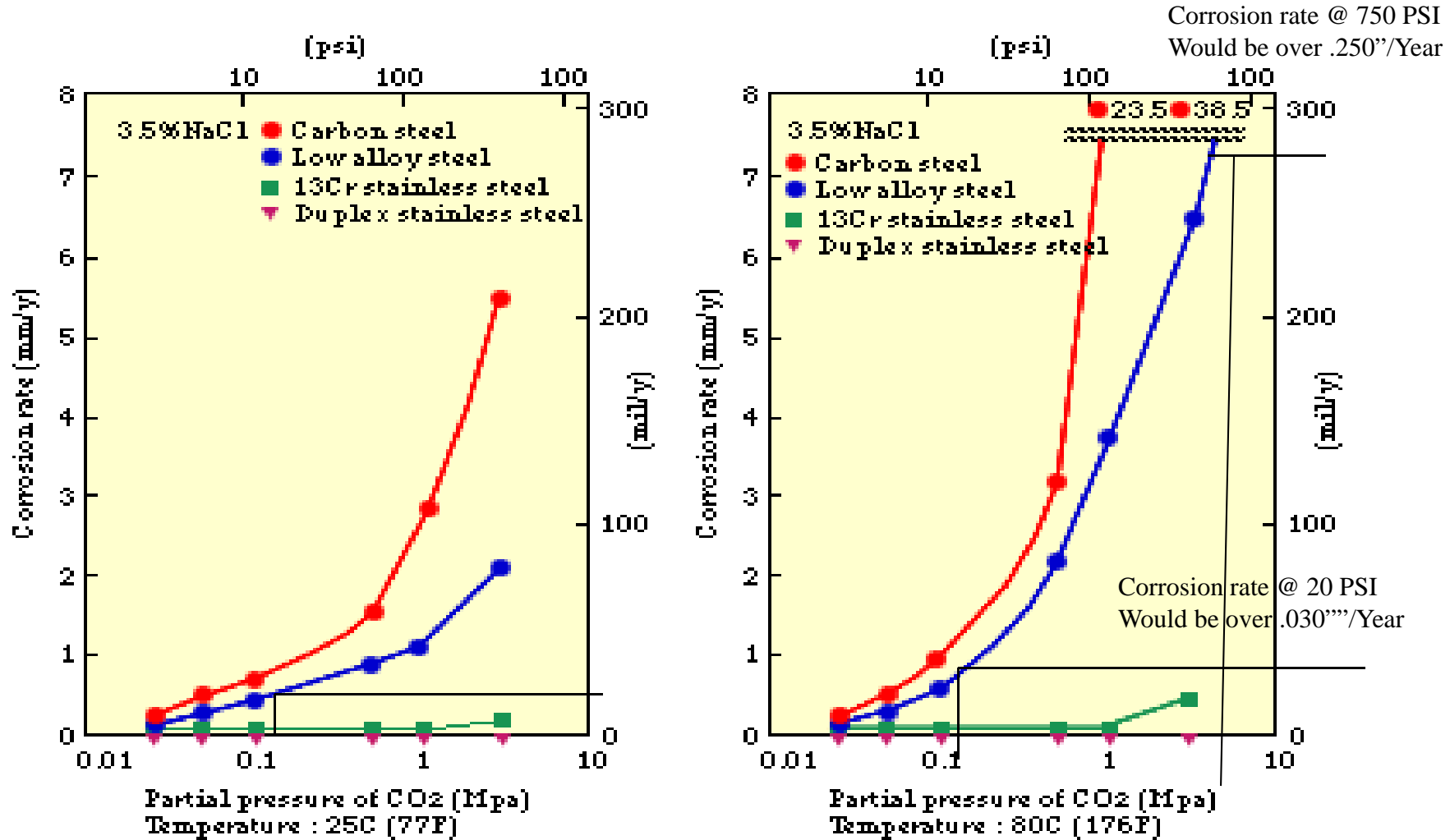
Test	General Corrosion	SSC NACE TM0177 Method C	SSC NACE TM0177 Method C
Temperature	330F	Ambient	330F
Applied Stress	N/A	90%AYS	90%AYS
Duration	14days	30days	30days
L80	70.5mpy	NF/NF	NF/NF
13CR-85	20.7mpy	NF/NF	NF/NF
HP2-95	3.4mpy	NF/NF	NF/NF
HP2-110	3.8mpy	NF/NF	NF/NF



**Remark : Characteristic of the film changes with temp., resulting in the complicated tendency (Carbon Steel and Low Alloy Steel).**

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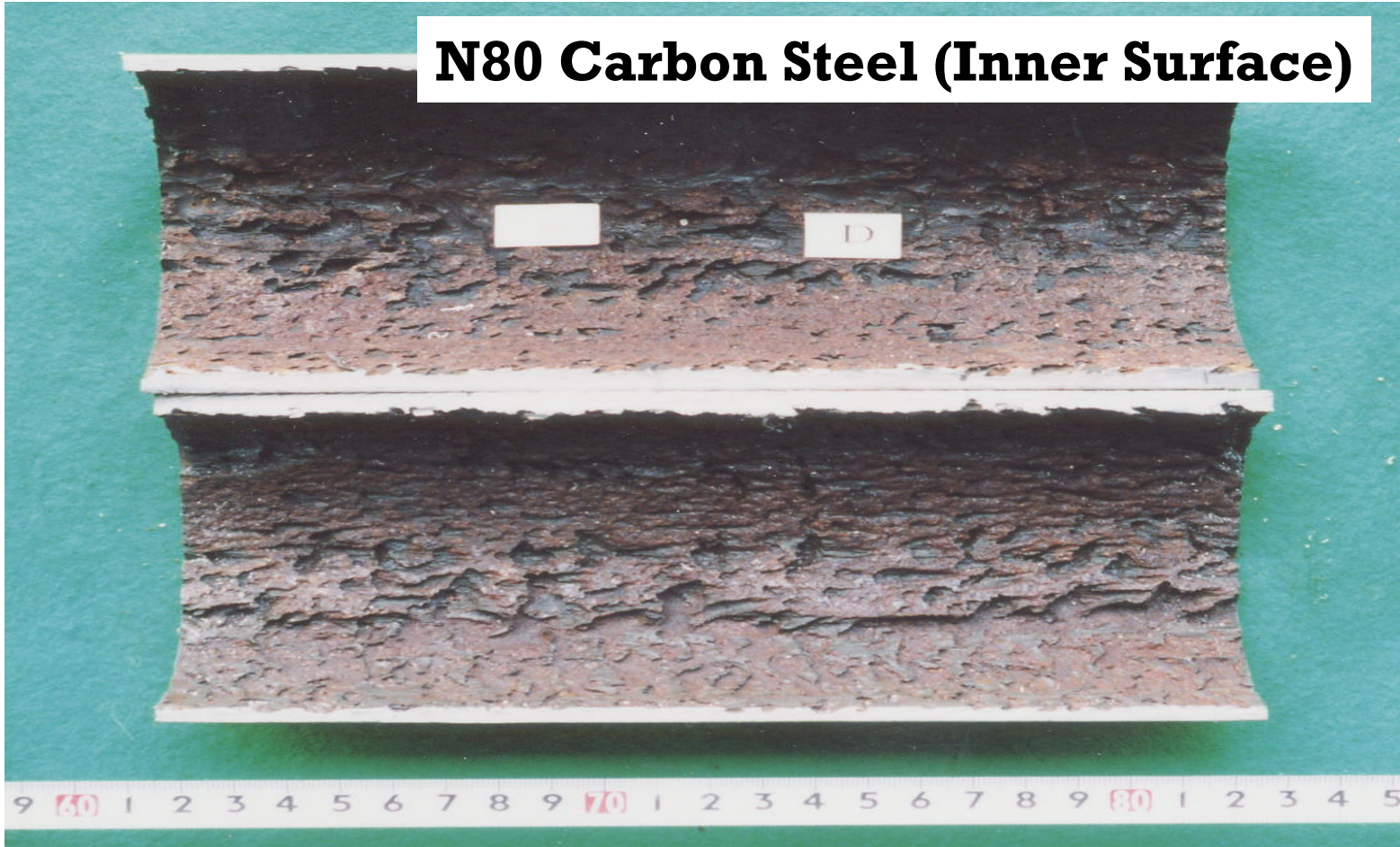
# Effect of Partial Pressure of CO<sub>2</sub> on Corrosion Rate



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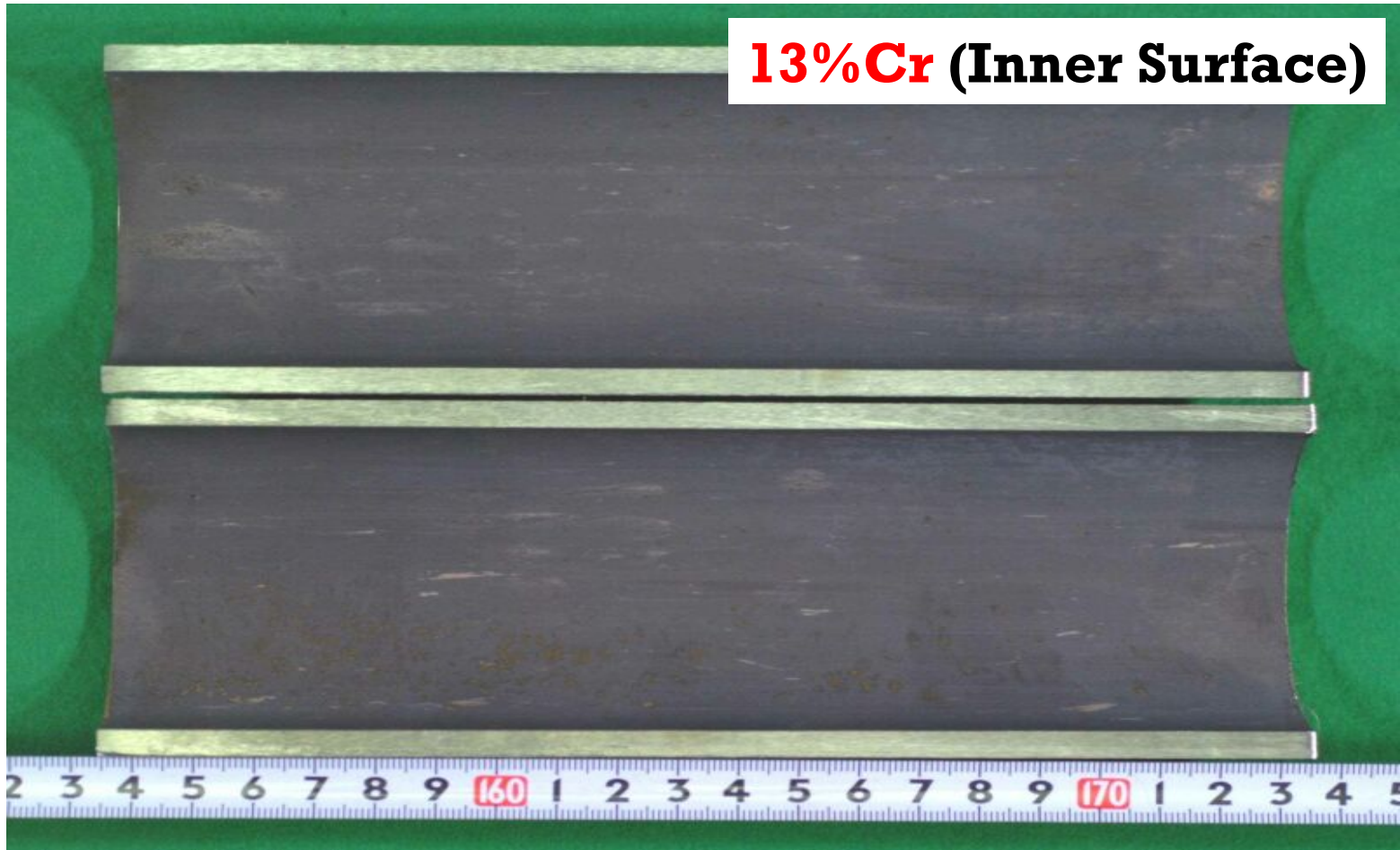
# General Corrosion

**N80 Carbon Steel (Inner Surface)**



After 1 year production      BHT: 118C (244F), CO<sub>2</sub>: 0.2MPa (28psi)

**13%Cr (Inner Surface)**



After 1 year production      BHT: 125C (260F), CO<sub>2</sub>: 0.8MPa (116psi)

# After 1 year of gas production in the **same** well

Well Condition

BHT: 125C (260F), BHP :80MPa (11600 psi), CO<sub>2</sub>: 1% (116 psi=0.8 MPa)

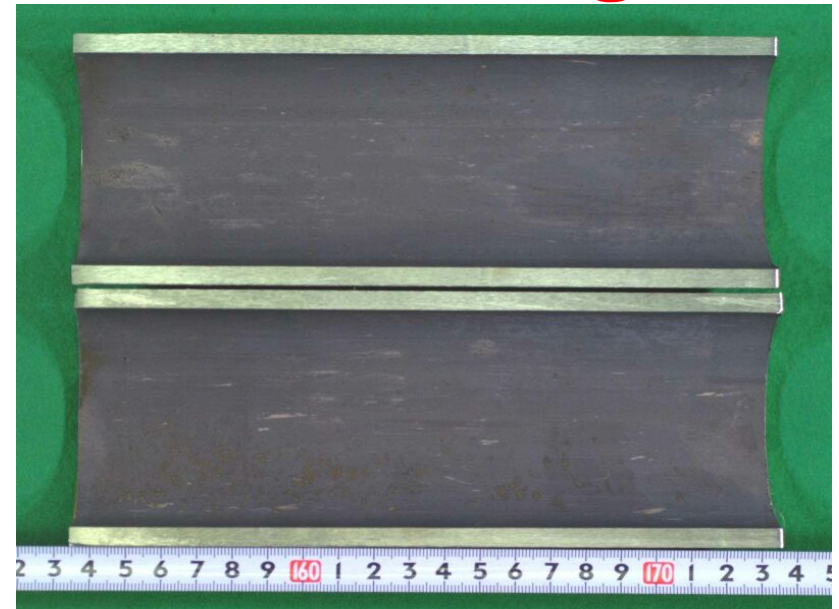
## Low Alloy Steel Hanger



**Heavy CO<sub>2</sub> Corrosion**

→The string has split  
at Low Alloy Steel Hanger

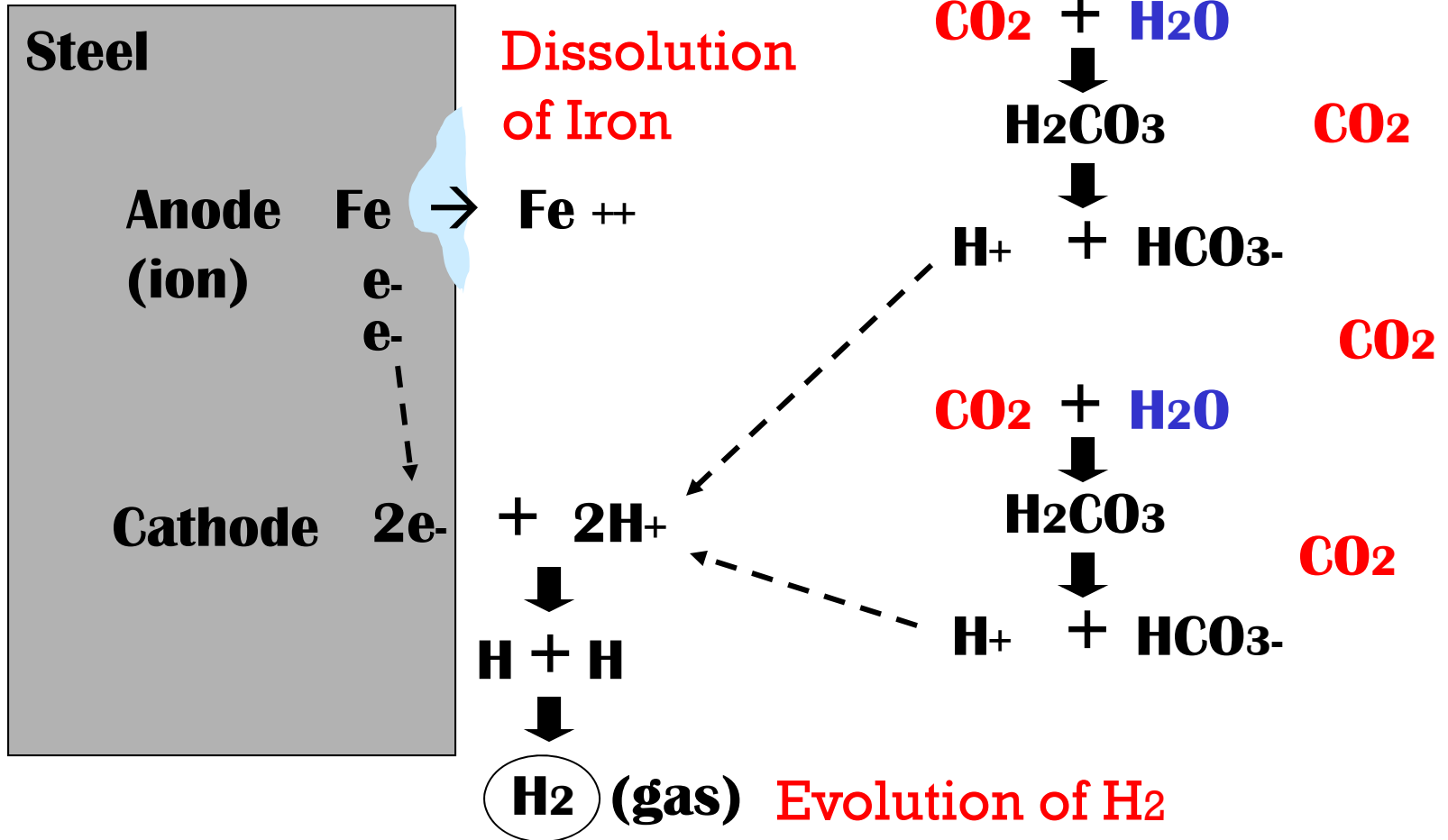
## 13Cr Steel Tubing



**Smooth Surface**

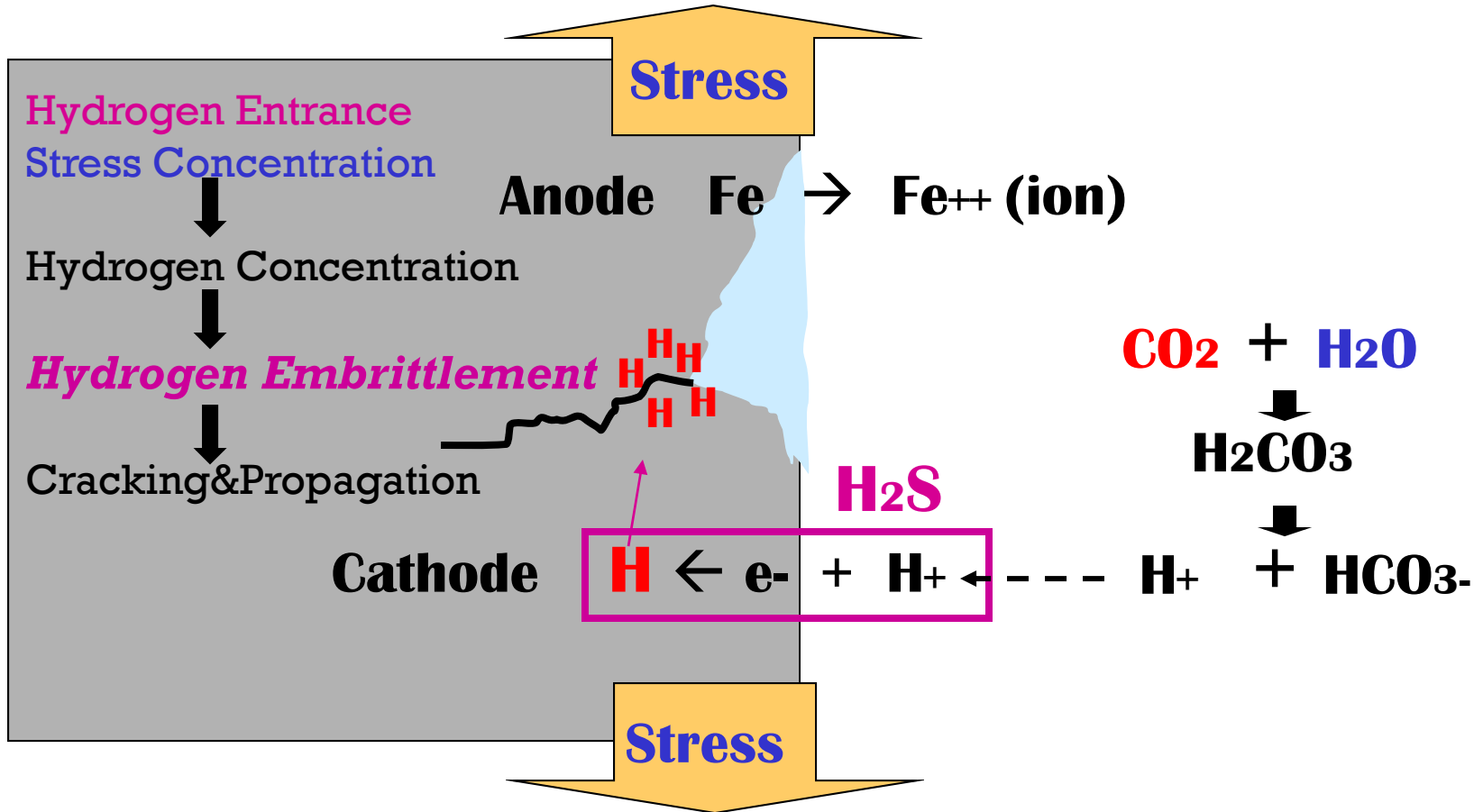
**No Corrosion**

# Mechanism of General (CO<sub>2</sub>) Corrosion



# (1) In the Sour Well

## → Sulfide Stress Cracking (SSC)



# Reference Information on Martensitic Stainless Steel

## 1. Chemistry

Material Grade	<b>C %</b>	<b>Si % max.</b>	<b>Mn %</b>	<b>P % max</b>	<b>S % max</b>	<b>Cr%</b>	<b>Ni %</b>	<b>Mo %</b>	<b>Cu % max</b>
<b>13Cr</b>	0.15-0.22	1.00	0.25-1.00	0.020	0.010	12.0-14.0	m ax. 0.50	-	0.25
<b>HP1-13Cr</b>	m ax. 0.04	0.50	m ax. 0.60	0.020	0.010	12.0-14.0	3.5-4.5	0.8-1.5	-
<b>HP2-13Cr</b>	m ax. 0.04	0.50	m ax. 0.60	0.020	0.010	12.0-14.0	4.5-5.5	1.8-2.5	-
<b>UHP-15Cr-125</b>	m ax. 0.04	0.50	m ax. 0.60	0.020	0.010	14.0-16.0	7.0-6.0	1.8-2.5	1.5

## 2. Grade and Application

Grade (ksi)	Chemistry	Application
<b>13Cr-80</b> <b>13Cr-85</b> <b>13Cr-95</b>	<b>13Cr</b>	<b>Sweet (CO<sub>2</sub>)</b>
<b>HP1-13Cr-95</b> <b>HP1-13Cr-110</b>	<b>13Cr-4Ni-1Mo</b>	<b>Severer Sweet (Higher Temp., Higher CO<sub>2</sub>)</b>
<b>HP2-13Cr-95</b> <b>HP2-13Cr-110</b>	<b>13Cr-5Ni-2Mo</b>	<b>Light Sour (Little H<sub>2</sub>S)</b>
<b>UHP-15Cr-125</b>	<b>15Cr-6Ni-2Mo</b>	<b>+ High Strength</b>

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# SSC Map A for Regular 13CR

(5%NaCl=30,300ppm)

NACE-TM0177-96 Method A mod.  
Applied Stress : 100%SMYS

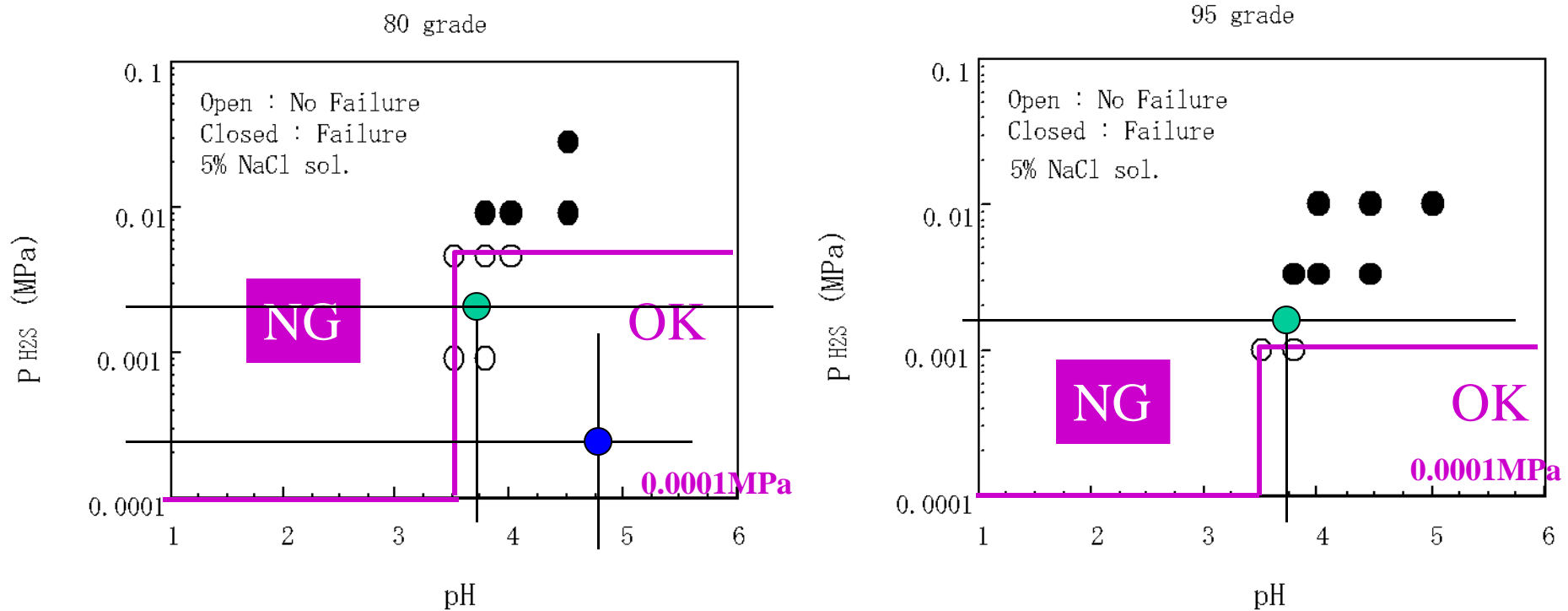


Figure A TENSILE SSC TEST RESULTS  
NACE-TM0177-96 Method A mod.  
Applied Stress : 100%SMYS

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# SSC Map A for **HP1-13CR** (13Cr-4Ni-1Mo) (5%NaCl=30,300ppm)

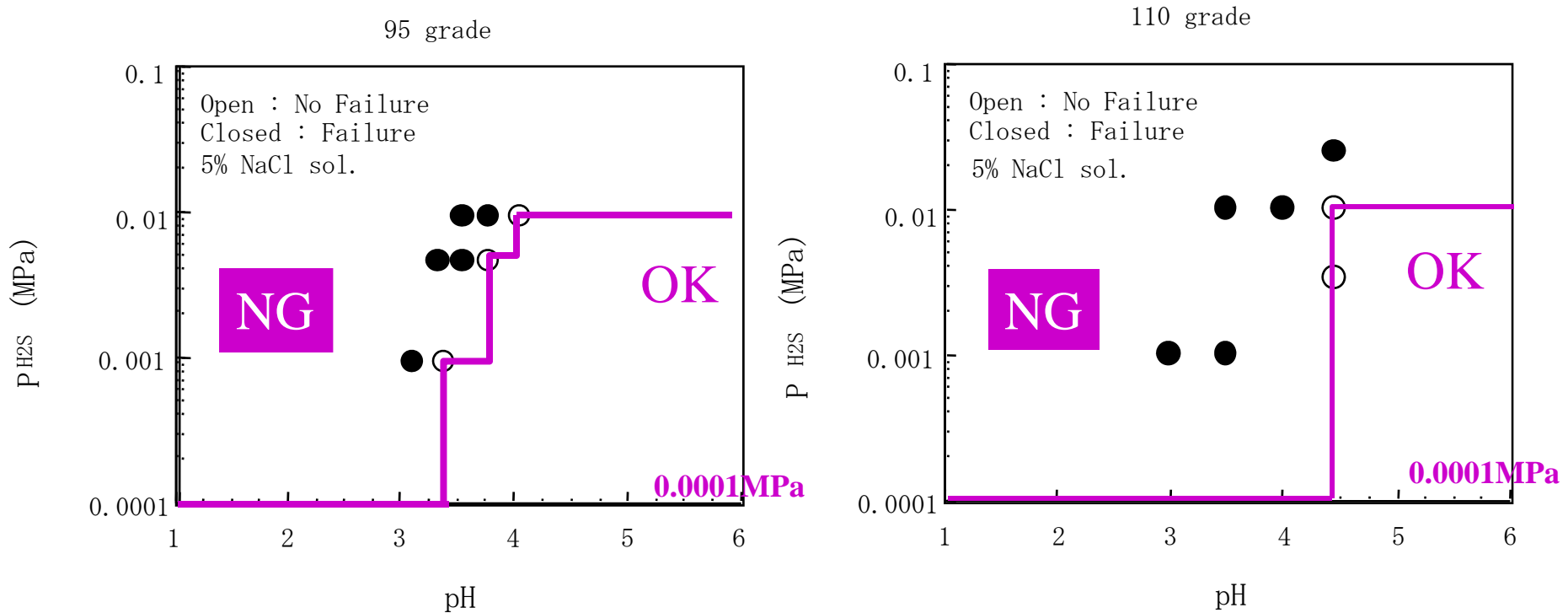


Figure A TENSILE SSC TEST RESULTS  
NACE-TM0177-96 Method A mod.  
Applied Stress : 100%SMYS

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# SSC Map for **HP2-13CR** (13Cr-5Ni-2Mo) (10%NaCl=60,600ppm)

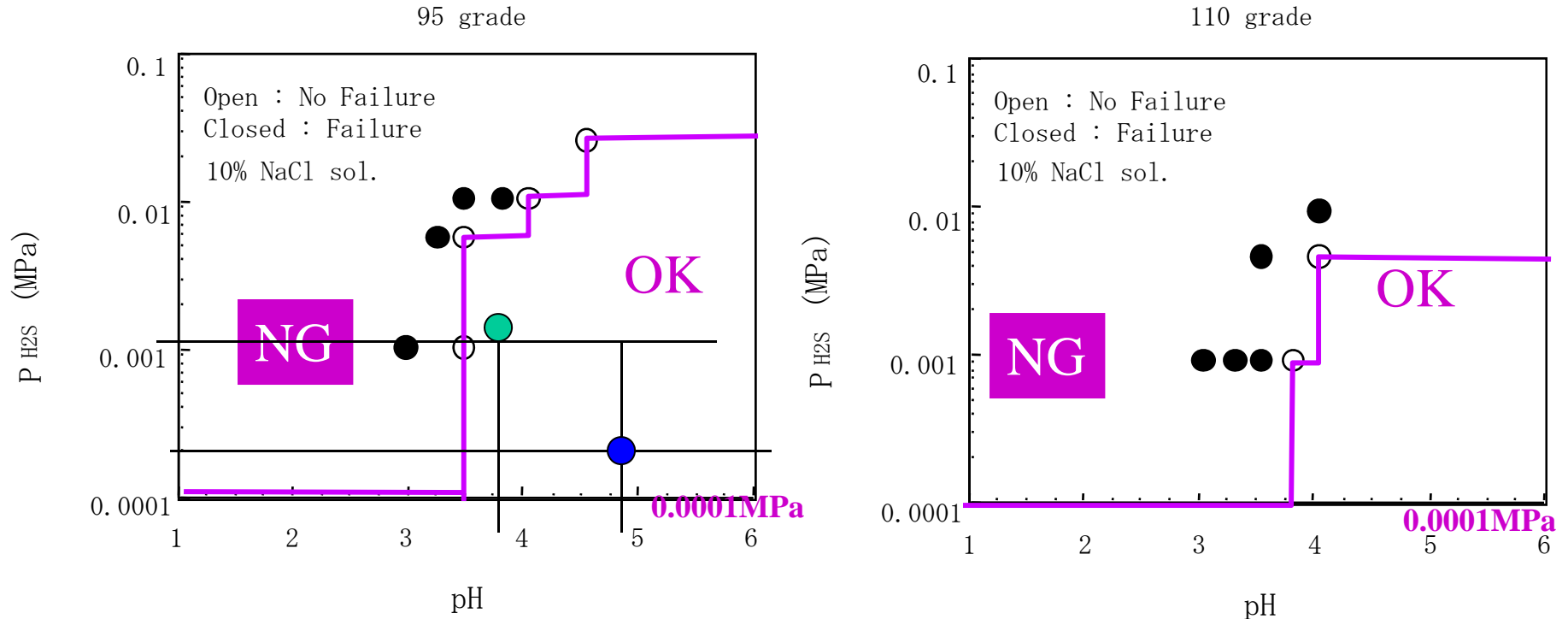
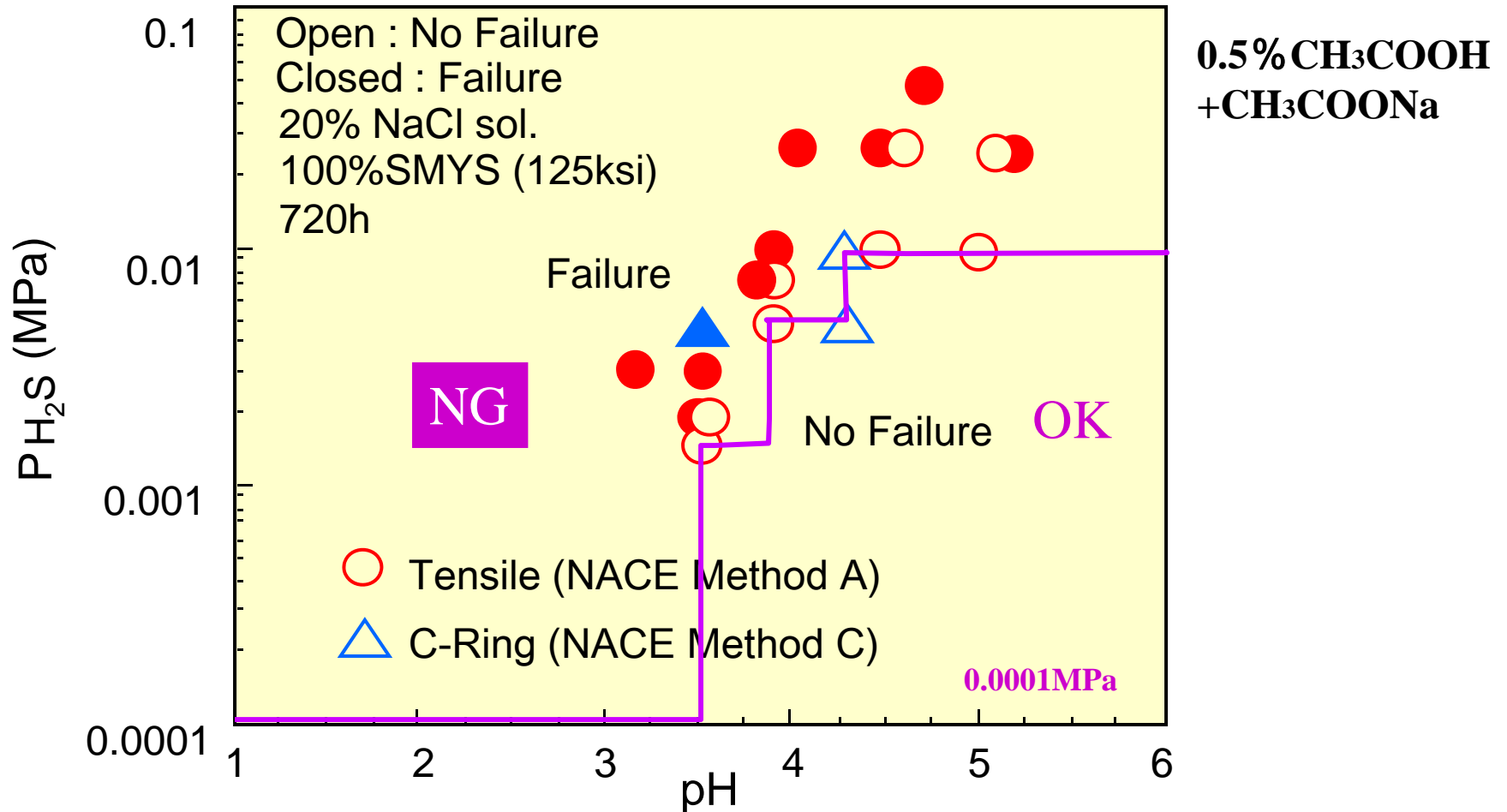


Figure 2-2 HP-II(13Cr-5Ni-2Mo) SSC map  
NACE-TM0177-96 Method A mod.  
Applied Stress : 100%SMYS

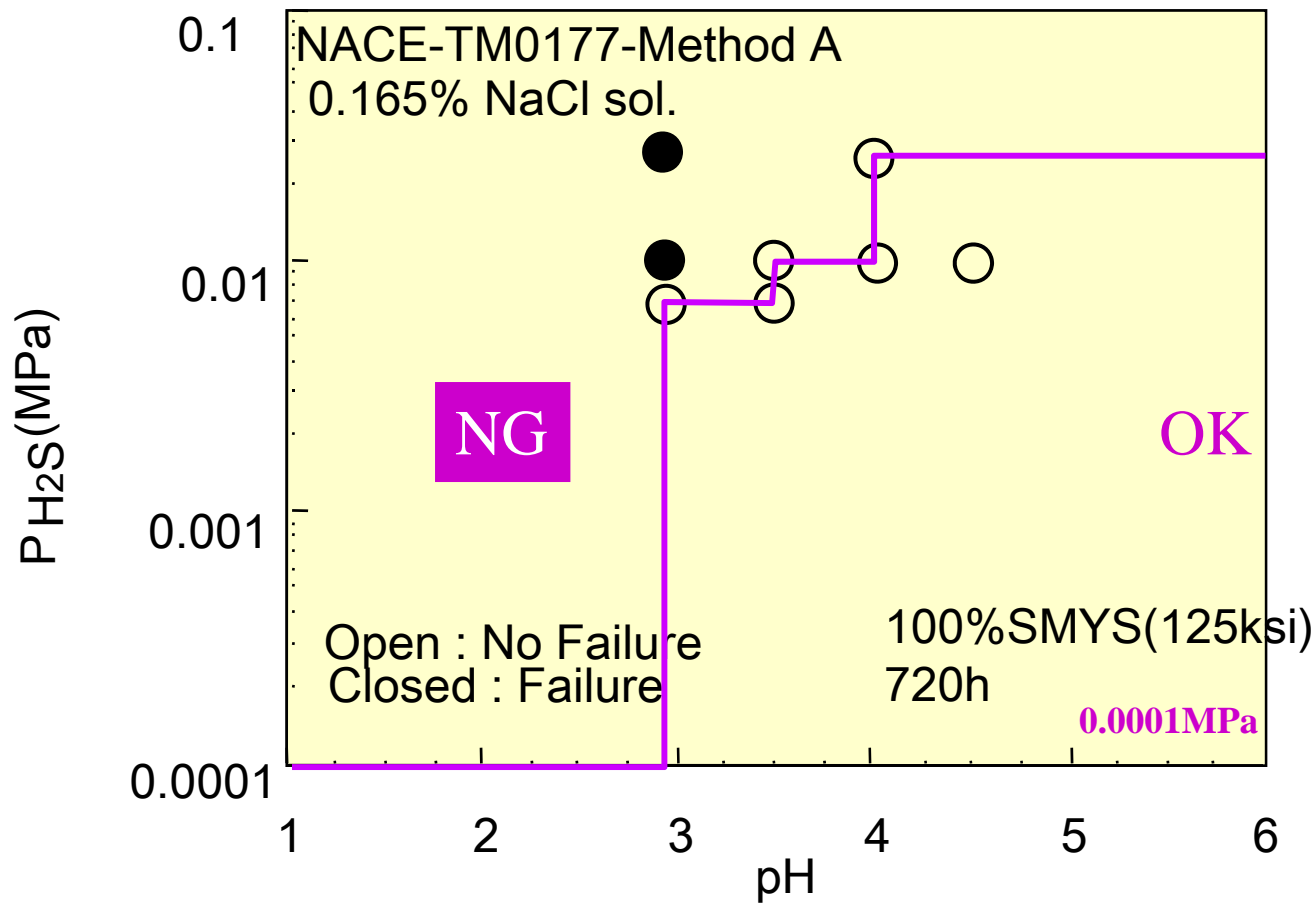
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# SSC Map A1 for **UHP-15CR-125** (15Cr-6Ni-2Mo) (20%NaCl=121,200ppm)



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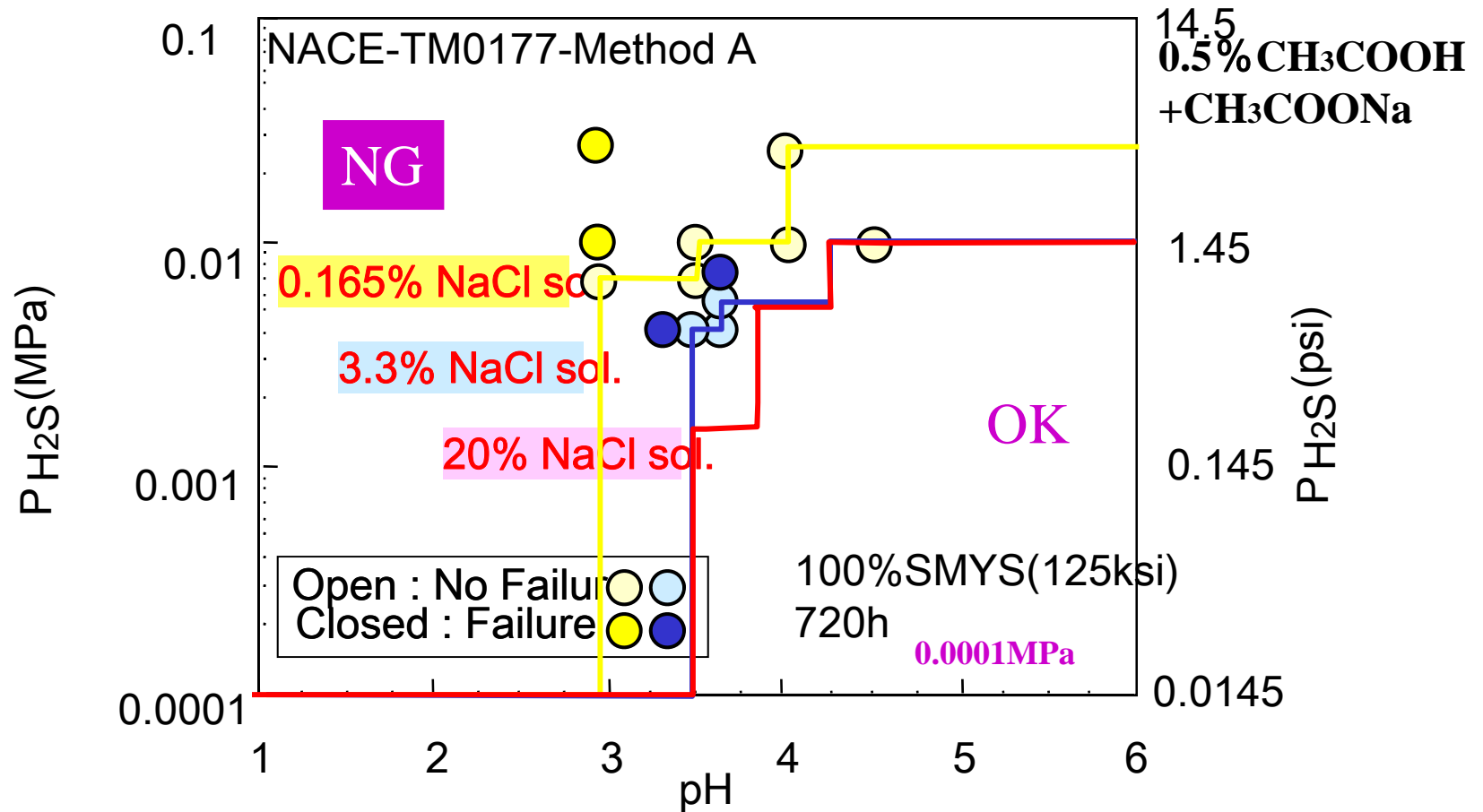
# SSC Map A2 for **UHP-15CR-125** (15Cr-6Ni-2Mo) (0.165%NaCl=1000ppm)



0.5% CH<sub>3</sub>COOH  
+ CH<sub>3</sub>COONa

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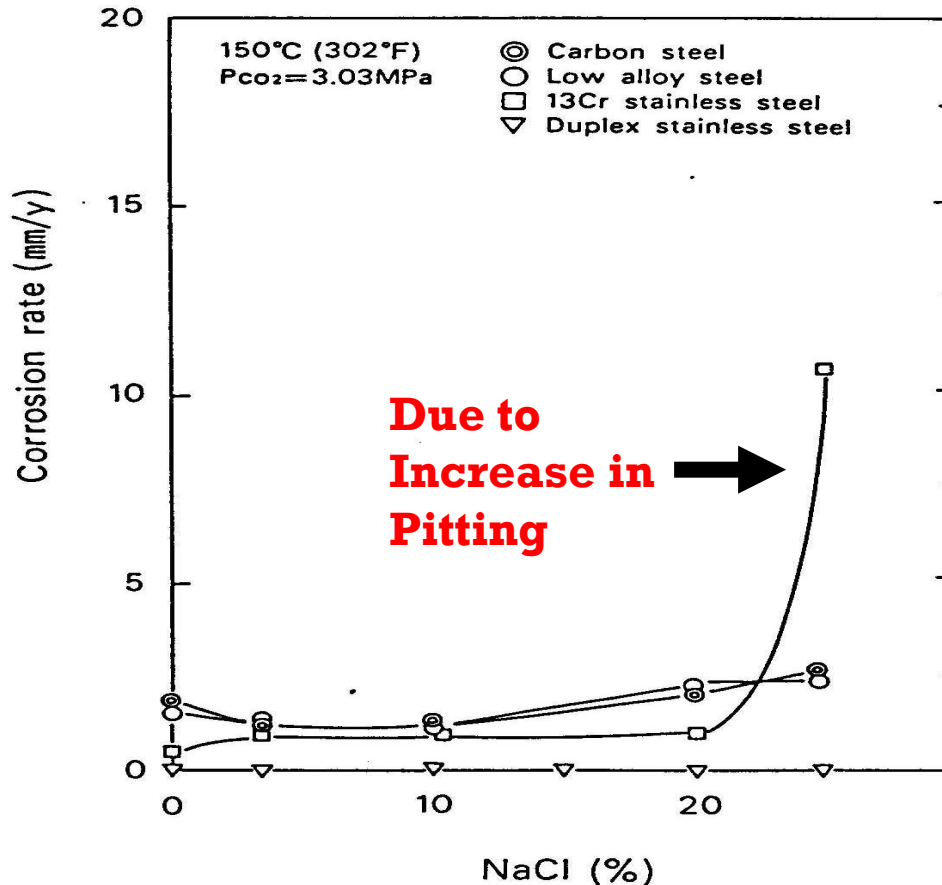
# SSC Map A3 for **UHP-15CR-125** (15Cr-6Ni-2Mo)



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# Effect of Chlorine on Corrosion/Pitting

## Data for Conventional 13CR



### Remark :

Generally, 13CR can be applied to the condition that contains **121,200 ppm of Cl<sup>-</sup> (=20%NaCl)**

Even if the Cl<sup>-</sup> is below 121,200 ppm, pitting can easily occur with **Oxygen presence**. Oxygen should be as low as 10 ppb.

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