Requirements for steel plates in sour service
Sour Service
an introduction in the world of hydrogen induced corrosion
Sour service damage is not a new issue!

- The oldest reports about sour service steel damage more than 60 years old

- Many organisations (like NACE or EFC), oil- and gas companies, engineering companies are still improving regulations

- The importance of hydrogen damage due to sour service is more and more recognised.

- The exploitation of sour gases and out of sour oil sources is rising. Often sweet sources get more and more sour.
Why this sensitivity to sour service damage?

- Sour media are aggressive to steel structures, damages not easy to detect.
- Health and safety of personnel and the public are in danger if precautions in survey of equipment and a right material selection are not adjusted.
- Severe environmental pollution could be the consequence out of such damages.
- Shutdowns due to material failures and the replacement of pressure vessels can cause dramatic economical loss.

A really bad example: Accident at Chicago refinery in 1984; 17 people killed.

Many good reasons for our full attention
Union Oil absorber vessel failure resulting from cracks growing in HAZ with no PWHT
The view of the steel plate manufacturer

- Steel plate requisitions reflect an increasing demand for plates with improved properties for sour service

- Large variety of customer requests:
  - many specifications based on published recommendations or test methods (e.g. NACE MR 0175, TM0284...)
  - in combination with the “in house”-experience and -prescriptions

- Aim of this paper:
  - general overview over the damaging mechanisms
  - general survey about the current specified requisitions for plate orders
  - Dillinger Hütte GTS possibilities to supply improved steel plates
Damaging Mechanisms

and

Test Methods
What are the sour service corrosion mechanisms?

Hydrogen-Induced Cracking (HIC) & Hydrogen Blistering

Sulfide Stress Cracking (SSC)

probably to be taken into consideration:

Stress-Oriented Hydrogen-Induced Cracking (SOHIC)
Cracking mechanism in the steel during H2S corrosion process

Acidic, H₂S-containing medium

- Hydrogen Sulfide
- Sulfide Ionics
- Proton
- Hydrogen Atom
- Electrons

Molecular Hydrogen

Steel with typical small imperfections
Corrosion reaction

\[ \text{H}_2\text{S} \rightarrow 2 \text{H}^+ + \text{S}^2^- \]

\[ \text{Fe} + 2 \text{H}^+ \rightarrow \text{Fe}^{2+} + 2 \text{H}_{\text{ad}} \]

\[ \text{Fe}^{2+} + \text{S}^2^- \rightarrow \text{FeS} \]

\[ \text{H}_2\text{S} + \text{Fe} \rightarrow \text{FeS} + 2 \text{H}_{\text{ab}} \]

\[ 2 \text{H}_{\text{ab}} \rightarrow \text{H}_2 \]
Schematical appearance of damage mechanisms in sour service

HIC / SWC

Blistering

SSC

SOHIC
Corrosion at stress free prismatic specimens

HIC
Hydrogen Induced Cracking

Definition as per NACE MR0175/ISO 15156:
Planar cracking that occurs in carbon and low alloy steels when atomic hydrogen diffuses into the steel and then combines to form molecular hydrogen at trap sites.
Requirements for steel plates in sour service

“Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking”

- **HIC**: Stepwise internal cracking on different planes of the metal; no external stress
- **origin**: 1984, for evaluation and comparison of test result
- **test solution**: pH 3 (sol. A) and pH 5 (sol. B) saturated with H$_2$S
- **test specimens**: position (one end/mid width), preparation, dimensions
- **duration**: 96 h
- **evaluation**: metallographic examination of cross sections
- **acceptance crit.**: to be agreed between purchaser and supplier
- **documentation**: CLR, CTR, CSR values for each section, specimen, test

NACE TM 0284-2003
Test specimen location acc. to NACE TM 0284

Test specimen location for plates up to 30 mm thick, inclusive (all dimensions in mm)

Test specimen location for plates over 30 mm to 88 mm, inclusive (all dimensions in mm)

Test specimen location for plates over 88 mm (all dimensions in mm)
HIC test method acc. to NACE TM 0284

Test duration: 96h
Test solution: saturated with H₂S

Solution A
- pH 3
- 5% NaCl, 0.5% CH₃COOH
- identical to Solution A of NACE TM 0177

Solution B
- pH 5
- synthetic seawater acc. ASTM D1141
Requirements for steel plates in sour service

6.1.3 If Solution A is used, the test solution shall be prepared in a separate sealed vessel that is purged with nitrogen for at least one hour at a rate of 100 mL per minute per liter of test solution prior to transferring the test solution to the test vessel. The test solution shall consist of 5.0 weight % NaCl and 0.50 weight % CH₃COOH in distilled or deionized water, i.e., 50.0 g of NaCl and 5.00 g of CH₃COOH shall be dissolved in each 945 g of distilled or deionized water. The initial pH shall be 2.7 ±0.1. All reagents added to the test solution shall be measured to ±1.0% of the quantities specified.

6.1.4 If Solution B is used, the test vessel shall be filled with synthetic seawater (see Paragraph 2.4) and the pH of the test solution measured and recorded. The pH of the synthetic seawater shall be within the range of 8.1 to 8.3 for the test to be valid. The test vessel shall then be sealed prior to purging and saturating with H₂S.

8.3 Test Solution

8.3.1 Test Solution A shall consist of 5.0 wt% NaCl and 0.5 wt% glacial acetic acid dissolved in distilled or deionized water. For example, 50.0 g of NaCl and 5.0 g of glacial acetic acid can be dissolved in 945 g of distilled or deionized water. Test Solution A shall be used unless the properties of Test Solution B (below) are required.
Requirements for steel plates in sour service

HIC test vessel
test specimens during HIC-test
Sectioning of test specimens

faces to be examined

rolling direction

Examination of the polished sections:

\[ \text{CLR} = \frac{\sum a}{W} \times 100\% \]

\[ \text{CTR} = \frac{\sum b}{T} \times 100\% \]

\[ \text{CSR} = \frac{\sum (a \times b)}{W \times T} \times 100\% \]

- \( a \) = crack length
- \( b \) = crack width
- \( W \) = specimen length
- \( T \) = specimen thickness

Crack distance < 0.5 mm => single crack
HIC or SWC damage
Hydrogen Blistering

A516 GR70 Amine Contactor\textsuperscript{1}

1: NACE RP0296
Hydrogen Blistering
Blister Cracking

Amine Contactor/Water Wash Tower\textsuperscript{1}

1: NACE RP0296
Corrosion at specimens under stress

SSC
Sulfide Stress Cracking

Definition as per NACE MR0175/ISO15156:

Cracking of metal involving corrosion and tensile stress (residual and/or applied) in the presence of water and \( \text{H}_2\text{S} \)
Requirements for steel plates in sour service

Verfasser/Dokument

Laboratory Testing of Metals for Resistance to Specific Forms of Environmental Cracking in H₂S Environments

4 test methods: tensile test (sol.A); preferred by DH-GTS¹
  Bent-Beam Test (sol. B)
  C-Ring test (sol. A)
  Double-Cantilever-Beam test (DCB) (sol.A)
2 test solutions: A: pH: 2.7; B: pH: 3.5, H₂S saturated
test duration: 720 h or until failure, whichever occurs first
results report: applied stress over log time (stress level of no fail. after 720h)
remark DH-GTS: acceptable only if PWHT plus DICREST route!
  no microalloying elements
1: also 4 point bend test acc. ASTM G39, sol.A (typ. linepipe)
Sulfide Stress Cracking

SSC in HAZ of head to shell weld of FCC absorber tower.
Sulfide Stress Cracking
SSC four-point bend test
SSC tensile test
SOHIC
Stress Orientated Stress Cracking

Definition as per NACE MR0175/ISO15156:

Staggered small cracks formed approximately perpendicular to the principle stress (residual or applied) resulting in a „ladder-like“ crack array linking (sometimes small) pre-existing HIC cracks.
Stress-Oriented Hydrogen Induced Cracking (SOHIC)

New phenomenon in the field of sour gas corrosion

- Sporadic documentation at spiral welded pipes and flaws in pressure vessels.

- Combination of rectangular (SSC type) and parallel cracks (HIC type) in the area of a multi dimensional tension field.

Typical SOHIC crack below a flaw. Created in a double beam bend test.
Stress-Oriented Hydrogen Induced Cracking (SOHIC)

SOHIC-Crack at a non PWHT repair weld of a primary absorber (deethanizer)\(^1\).

1: NACE RP0296
Stress-Oriented Hydrogen Induced Cracking (SOHIC)

- issue - still under large discussion
- mechanism not fully understood
- mixture of SSC and HIC type cracking
- location close to the welds
SOHIC test as per NACE TM0103 / 2003

• SOHIC testing
  • 4 point bent double beam tests
  • test duration 168 h
  • metallographic examination of the cross sections
  • Reasonable acceptance criteria for CCL (Continuous Crack Length), DCL (Discontinuous Crack Length) and TCL (Total Crack Length) are not yet reported
SOHIC test arrangement as per NACE TM0103 / 2003

NACE TM0103 – Full Size Double-Beam Test Specimen Design

$\text{EDM slot using 0.2-mm (0.008-in.) dia. wire}$

$\begin{align*}
\text{t} &= \text{thickness of beam (mm [in.])} \\
\text{L} &= \text{distance between bolt centerlines (mm [in.])} \\
\text{a} &= \text{distance between bolt and spacer centerlines (mm [in.])}
\end{align*}$
Dimensions of the notch: Depth = 2mm, r = 0.13mm

Sectioning across the notch into two cross sections.

SOHIC test specimens as per NACE TM0103 / 2003
SOHIC evaluation of the cross sections from the double beam specimens

CCL - continuous cracks (perpendicular) in the most stressed area near to the bottom of the notch.

DCL - discontinuous (parallel) cracks below the continuous crack area, with lower stresses.

TCL - length of the whole cracked area.
Results of the SOHIC tests at Dillinger Hütte GTS (1)

Although the tests were performed with HIC resistant DICREST material, at a load of less than 50% yield in pH3 solution first SOHIC type cracks appeared.

Rising the load increases the appearance of these cracks.

Testing in pH5 solution no SOHIC cracks are detected.

The notch of specimens generates a very (too ?) harmful stressed area.
It should be taken into consideration, whether a notch like this is permitted generally at pressure vessels.

This could explain why even HIC and SSC resistant steels (DICREST) show big amounts of SOHIC cracks with the proposed test method.

Acc. to DH’s opinion this test method is not appropriate as SOHIC test.

SOHIC resistant material (acc. to this test method) can not be produced with normalised steels. It seems to be that Q+T material will reach this aim.
SSC + HIC
NACE MR0175/ISO 15156 - 2003

“Petroleum and natural gas industries—Materials for use in H$_2$S- containing environments in oil and gas production”

• By the end of 2003 NACE0175/ISO15156 was published giving **requirements** and **recommendations** for the **selection** and **qualification** of **carbon and low-alloy steels**, corrosion-resistant alloys, and other alloys for service in equipment used in oil and natural gas production and natural gas treatment plants in H$_2$S-containing environments

• 3 parts:  
  - Part 1: General principles for selection of cracking-resistant materials  
  - Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons  
  - Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys

• Qualification route for steels not yet proved to be suitable for H$_2$S service
SSC in NACE MR0175/ISO 15156 - 2003

SSC: Metal cracking under corrosion in presence of H₂S and stress; same time hydrogen embrittlement especially in steel with high hardness or high strength

SSC and SCC susceptibility depends on e. g.:
- steel: chemical composition, heat treatment, microstructure, cold deformation
- hydrogen activity (pH-value)
- total tensile stress (including residual stress)
- temperature, duration, ...

- Definition of SSC severity levels from 0 to 3 with increasing severity
- severity level 1 starting from H₂S partial pressure \( \geq 0.0003 \) MPa
- No absolute resistance, material can fail in SSC-tests!
Requirements:

Pressure vessel steels classified as P-No 1, group 1 or 2 in Section IX of the ASME Boiler and Pressure Vessel Code are acceptable without testing.

Carbon & low alloy steels:
- heat treated (contr. Rolled, N, N+T, Q+T);
- Ni < 1% wt
- Hardness < 22 HRC (average) < 24 HRC (individual)

Fabrication conditions:
* welding and PWHT have to respect 22HRC limitation also in HAZ and WM
* > 5% cold deformation ⇒ SR to be applied

Remark of the steel producer:
NACE MR0175 shall prevent SSC-Cracking, but there is very few influence on steel making practice (⇒ no influence on HIC-resistance!!)
# Requirements for steel plates in sour service

## Listing of Section IX of the ASME Boiler & Pressure Vessel Code

### P-No.1, Group 1

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<thead>
<tr>
<th>Spec</th>
<th>Grade</th>
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<td>A, B, C, D</td>
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<tr>
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<td>C</td>
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<td>SA-738</td>
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HIC in NACE MR0175/ISO 15156 – 2003

- The user shall consider HIC and HIC testing even if there are only trace amounts of H₂S present

- HIC susceptibility is influenced by chemistry and manufacturing route

Requirements

- low Sulphur content ( < 0,003 %)

- test acc. to NACE TM0284

- acceptance criteria (solution A: CLR ≤ 15%, CTR ≤ 5%, CSR ≤ 2%)

- other conditions may be defined as per table B.3 for specific or less severe duty
User should consider SOHIC when evaluating carbon steels

- Pre-qualification to SSC prior to SOHIC/SZC evaluation
- Small-scale tests: unfailed uniaxial tensile (UT) & four point bend (FPB) specimen are metallographically examined
  - UT-specimen: no ladderlike HIC indications or cracks exceeding 0.5mm in through thickness direction allowed
  - after hydrogen effusion the tensile strength shall not be less than 80% of the tensile strength of unused specimens
  - FPB-specimen: no ladderlike HIC indications or cracks exceeding 0.5mm in through thickness direction allowed
  - blisters less than 1mm below the surface and blisters due to compression regardless of the depth shall be disregarded
- Full pipe ring tests may be used, test method and acceptance criteria described in HSE OTI-95-635
EFC 16

“Guidelines on Materials Requirements for Carbon and Low alloy Steels for H2S-Containing Environments in Oil and Gas Production Combined specification for test methods of HIC and SSC”

concerns: C- and low alloy steels in oil and gas production (not in refinery service); conclusion of NACE-test methods

published: in 1995, rev. 2 in 2002

1. HIC

- low S, shape control, low segregation, low CEQ

- test acc. to NACE TM0284, Solution A

- acceptance criteria: CLR \leq 15\%, CTR \leq 5\%, CSR \leq 1.5\%
EFC 16 (2)

2. SSC

- \( f(\text{pH-value/ H2S-p.pressure}) \): Non sour, transition region, sour service

- in case of sour service: see guidelines
  * limited hardness in HAZ to max. 250 HV30 except cap´s cap layer up to 275 HV30 (t < 9,5mm) or 300 HV30 (t > 9,5mm)
  * limited cold deformation (5% for PV) or PWHT > 620°/650°C

- various test methods for the evaluation of SSC resistance (uniaxial, 4point-bend, C-ring,....); pH= 3;
  DH recommend the tensile test and 4 point bend test

- load and duration of the test to be agreed; proposals are made recommendation of DH-GTS e.g.: load: 0.72 SMYS; duration: 720 h

3. SOHIC/ SZC (Soft zone cracking)

- PWHT recommended

- testing the susceptibility by 4 point bend test as an option, however no acceptance criteria defined
HIC + SSC
Requirements for steel plates in sour service

“Guidelines for Detection, Repair and Mitigation of Cracking of Existing Petroleum Refinery Pressure Vessels in Wet H₂S Environments”

- Concerns HIC, SSC, SOHIC, ASCC (Alkaline Stress C.C.)
- Applicable for existing equipment in refineries made of carbon steel
- Valid if H₂S concentration ≥ 50 ppm (but no threshold concentration defined)
- Reports about the parameters for each damage mechanism
- Reports about a large survey (in 1990) of 5000 (!) inspected pressure vessels
- 26% of all vessels showed cracking incidence (crack depth from 1.6 mm to more than 25 mm)
- Recommendations for inspection
“Guidelines for Detection, Repair and Mitigation of Cracking of Existing Petroleum Refinery Pressure Vessels in Wet \( \text{H}_2\text{S} \) Environments”

- **Definition of environment to be more susceptible to HIC, SOHIC or blistering**
  - process temp.: Ambient to 150 °C
  - \( \text{H}_2\text{S} \): > 2000ppm + ph > 7.8
  - \( \text{H}_2\text{S} \): > 50 ppm + ph < 5
  - presence of HCN + others

- **Recommendations for repair:**
  - Hardness of production welds < 200 HB
  - Welding procedure qualification hardness < 248 HV10 for HAZ and WELD
  - PWHT to be considered
NACE MR0103 – 2003

„Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining environments“

NACE MR0175: for oil- and gas handling systems
NACE MR0103: for refinery service; it is based on the experience with MR0175 and other NACE publications.

Specific Process Conditions:
- > 50 ppm H₂S dissolved in H₂O or if
- pH < 4 + some H₂S or if
- pH > 7.6 + 20 ppm HCN + some H₂S or if
- > 0.05 PSIA H₂S in gas phase
- Also reference to NACE RP0472 requirements
NACE MR0103 – 2003 (2)

„Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining environments“

Responsibility of the user:
- HAZ - hardness
- Residual stresses
- $R_m$ increase $\Rightarrow$ risk increase

Hardness Base Metal < 22 HRC (or also 248 HV 10)
Cold deformation < 5% otherwise stress relieved
Production of HIC-resistant steels
How to produce HIC and SSC-resistant steel plates?

Basis:

Well developed know how (Dillinger Hütte GTS has been engaged in this field for more than 20 years)

Adequate production installations

Permanent exchange with the endusers

Follow up in international research projects
Requirements for homogeneous Dillinger Crack Resistant Steel plates

DICREST-route

- hot metal desulphurisation
- deep vacuum degassing
- special chemical composition (C, Mn, S, P)
- cleanliness stirring by Argon
- special casting parameter (no bulging, adapted superheating)
- intensified QA-process
- special care to avoid unacceptable segregations
- high shape factor rolling (strong reduction in thickness per rolling pass)
## Production route in the steel plant

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
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<tbody>
<tr>
<td>Hot metal desulphurisation</td>
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</tr>
<tr>
<td>BOF converter</td>
<td></td>
</tr>
<tr>
<td>Argon stirring process</td>
<td></td>
</tr>
<tr>
<td>Heating</td>
<td></td>
</tr>
<tr>
<td>Degassing process</td>
<td></td>
</tr>
<tr>
<td>Casting</td>
<td></td>
</tr>
</tbody>
</table>

### Objective:
- **hot metal desulphurisation**
- **dephosphorisation**
- **decarburisation**
- **denitrogenisation**
- **slag conditioning, steel desulphurisation**
- **temperature adjustment**
- **removal of:**
  - Carbon
  - Sulphur
  - Nitrogen
  - Hydrogen
- **cleanliness avoiding:**
  - reoxidation
  - resulphurisation

![Diagram of production route in the steel plant](image)
Inclusion distribution for different caster types

- **Vertical caster**
- **Curved caster**

![Diagram showing inclusion distribution for different caster types with graphs plotting total oxygen in ppm against distance from the fixed side in % for curved and vertical casters.](image-url)
Results from HIC test, according to NACE TM 0284-96, for one single heat in dependence of the cast length of DICREST 15 pressure vessel steel; test solution acc. to TM 0284-96: A (pH3).
Influence of High Shape Factor Rolling

Rolling Shape Factor = \( \frac{2 \sqrt{R(t_o - t_i)}}{t_o + t_i} = m \)

\[
\text{Reduction} = \frac{t_o - t_i}{t_o} \times 100\%
\]

a) \( \epsilon_t = 1.71 \ (250 \rightarrow 146\text{mm}) \) / 12 passes

b) \( \epsilon_t = 1.71 \ (250 \rightarrow 146\text{mm}) \) / 3 passes

1st stand (5.5m-4-high stand)
Work roll \( \Phi \) : 1180mm
Max. torque: 2 x 4500kNm
AC synchr. motor
(2 x 108000kW)
Max. force 108000kN
Optimized production steps for DICREST plates in the heavy plate mill
Aspects of quality assurance: casting incidents

Example of deviation in casting parameter combination

- Incident risk range
  - Additional testing prohibited from release
  - Additional testing

Acceptance criteria

Cracking extend in HIC test vs. cast strand length position
Test laboratory of Dillinger Hütte GTS to measure sour gas susceptibility:

Equipment:

- 8 laboratory fume hoods (7 for tests, 1 for cleaning)
- Overall 39 connections for tests vessels
- 12 connections for SSC tensile tests (CorTest rings) equipped with computer aided monitoring of specimen failure
- 3 independent gas supply systems for parallel use of 3 different types of test gases
- Temperature adjustment and control system

Additionally health and safety-installations:
gas detection systems, flame guard system to maintain $\text{H}_2\text{S}$ combustion, activated carbon filters in the exhaust air conduit, collecting tanks for all waste waters from the process
Sour service

What can DH offer?
Actual statistics of requested standards and thicknesses

About 5% of the overall DICREST tonnage is requested in grades other than SA 516
## Dillinger Hütte’s standardised offer for HIC resistant plates: DICREST

<table>
<thead>
<tr>
<th>grade</th>
<th>max. plate thickness</th>
<th>test solution acc. TM 0284-96</th>
<th>acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>DICREST 5</td>
<td>80 mm</td>
<td>A (pH 3)</td>
<td>CLR: ≤ 5, CTR: ≤ 1.5, CSR: ≤ 0.5</td>
</tr>
<tr>
<td>DICREST 10</td>
<td>80 mm</td>
<td>A (pH 3)</td>
<td>CLR: ≤ 10, CTR: ≤ 3, CSR: ≤ 1</td>
</tr>
<tr>
<td>DICREST 15</td>
<td>150 mm</td>
<td>A (pH 3), B (pH 5)</td>
<td>CLR: ≤ 15, CTR: ≤ 5, CSR: ≤ 2</td>
</tr>
</tbody>
</table>

1) The requested test solution must be stated in the order in case of DICREST 15.

\[
CLR = \frac{\sum a_i}{W} \cdot 100\%
\]

\[
CTR = \frac{\sum b_i}{T} \cdot 100\%
\]

\[
CSR = \frac{\sum (a_i \cdot b_i)}{W \cdot T} \cdot 100\%
\]

**Note:** Acceptance criteria are defined as the average of all sections of all specimens per plate.

ETC = Extent of transverse cracking = \(b_{max}\)

ELC = Extent of longitudinal cracking = \(a_{max}\)
Actual acceptance levels for DICREST 5 plates in pH3 solution HIC tested in dependence on averaging the values for a certain no. of section

<table>
<thead>
<tr>
<th>No. of sections</th>
<th>plate thickness</th>
<th>CLR ≤</th>
<th>CTR ≤</th>
<th>CSR ≤</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>t ≤ 30mm</td>
<td>15%</td>
<td>5%</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td>30mm &lt; t ≤ 40mm</td>
<td>15%</td>
<td>3%</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td>40mm &lt; t ≤ 110mm</td>
<td>15%</td>
<td>3%</td>
<td>0.1%</td>
</tr>
<tr>
<td>3</td>
<td>t ≤ 30mm</td>
<td>10%</td>
<td>3%</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td>30mm &lt; t ≤ 110mm</td>
<td>10%</td>
<td>2%</td>
<td>0.1%</td>
</tr>
<tr>
<td>9 resp. 15*</td>
<td>t ≤ 15mm</td>
<td>5%</td>
<td>1.5%</td>
<td>0.5%</td>
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<tr>
<td></td>
<td>15mm &lt; t ≤ 30mm</td>
<td>5%</td>
<td>1.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td>30mm &lt; t ≤ 110mm</td>
<td>5%</td>
<td>1%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

* No. of Sections acc. to NACE TM0284-03 for t > 88mm = 15

Remark: All other requirements on request
Optimisation of CLR-values in NACE TM 0284-96, solution A through application of special DICREST-production route (steel grades: A 516 Gr. 60, 65 and 70; plate thickness 6-80 mm) compared to Pseudo HIC-plates with a package of certain Pseudo-HIC measures.
1.2.4 Pseudo-HIC Resistant steel shall not be used to fabricate equipment intended for sour service application. Steel that passes the HIC test, but has not been initially manufactured to be HIC resistant steel shall not be used.
DICREST ex mill and ex stock

Dillinger HIC resistant pressure vessel plates

From stock

ANCOFER WALDRAM STEELPLATES

Stadendamweg 81
4905 AD Oosterhout (nl)
P.O. Box 190 • 4900 AD Oosterhout (nl)
The Netherlands
Phone: +31 162 491500
Fax: +31 162 429806
info@AWS.dillinger.biz • www.ancoferwaldram.nl

Now also from stock

DILLINGER MIDDLE EAST FZE

Road 1241, Between Junction 12 & 13
Postfach: 17592, Jebel Ali,
Dubai, United Arab Emirates
Phone: +971 4 8 83 38 94
Fax: +971 4 8 83 38 95
randhir.venugopal@dme.dillinger.biz
pjnarayanan@dme.dillinger.biz
sales@dme.dillinger.biz

P.O. Box 1580
66748 Dillingen
Germany
Phone: +49 6831 47-3453
Fax: +49 6831 47-3089
info@dillinger.biz • www.dillinger.de
Specification details of DICREST stock plates (AWS)

- thickness: 8 -80 mm
- grades SA 516 grade 60, 65 or 70
- delivery condition: normalised
- toughness requirements acc. SA20-S5
- HIC testing frequency: per heat on the thinnest and thickest plate
- HIC test per NACE TM0284-2003, solution A (pH3)
- hot tensile test at 400°C
- ultrasonic testing: acc. A578 (ed. 2001) S 2.2
- additionally: - conformity in harness and Ni-content to NACE MR0175
  - banding check acc. to E 1268 once per heat for information
- DiME specification is more customized especially for Middle Eastern market in thickness range from 10 to 50 mm
Conclusion

- Sour service becomes more and more important; research and standardising efforts further ongoing

- 2 (3) major failure mechanisms are important (HIC, SSC and probably SOHIC)

- SSC rules have low influence on steel making practice. The phenomenon is mostly seen at hard HAZ or hard base metal. DH-GTS applies DICREST route.

- SOHIC is not quite fully understood. Most appearances are related to failures in HAZ; no proper test method; research is going on. Q+T steels show advantages.

- HIC resistant steels need a special manufacturing route and require a lot of experience & know how
Dillinger Hütte GTS is prepared for the needs of sour service

We contribute with 450,000 t of HIC resistant\(^1\) linepipe and pv-plates per year

\(^1\) with certified HIC-resistance
We can not transform sour to sweet...

... but we can help you take it with a smile!