

API 579-1/ASME FFS-1
Fitness-For-Service Evaluation
(Virtual Classroom)

- Question will be answered at the end of each section
- Please accept our apologies if we do not have the time to answer all your question
- For further enquiry, training or quote you can contact us at info@fitnessforservice.ir

General

Part 7 in API579 utilizes for FFS Assessment for low strength ferritic steel pressurized components with Hydrogen Induced Cracking (HIC) in Wet H₂S Environments.

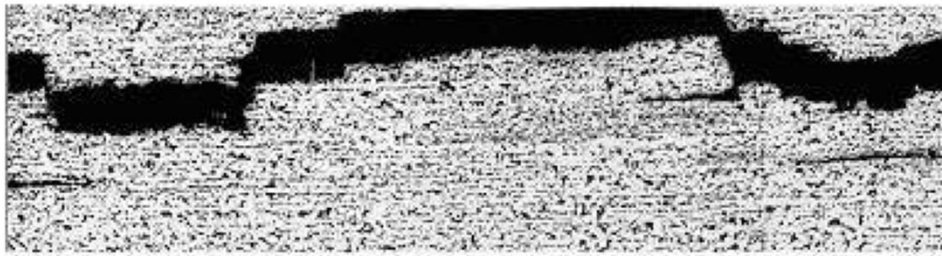


Figure 3-67-4—High-magnification photomicrograph of HIC damage.

HIC is characterized by **laminar (in-plane) cracking** with some associated through thickness crack linkage. This is sometimes referred to as **step-wise cracking (SWC)**, due to its morphology. This type of damage typically occurs in carbon steel plates exposed to an aqueous phase containing hydrogen sulfide, cyanides, hydrofluoric acid, or other species which charge atomic hydrogen into the steel.

PART 7 – ASSESSMENT OF HYDROGEN BLISTERS AND HYDROGEN DAMAGE ASSOCIATED WITH HIC AND SOHIC

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Applicability and Limitations of the FFS Assessment based on Part 7

- The procedures apply to components whose operating temperature is **less than 204°C (400°F)** for carbon or low alloy steels or are below the applicable design curve in API RP 941 Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants, whichever is greater.

Damage associated with high temperature hydrogen attack (HTHA) is excluded from this assessment.

Applicability of the Level 1 and Level 2 Assessment Procedures

1. The original design criteria were in accordance with a recognized code or standard.
2. The material is considered to have sufficient toughness.
3. The component is not in cyclic service (i.e., pressure and/or temperature variations including operational changes and start-ups and shut-downs).
4. The following limitations on component types and applied loads are satisfied:
 - ☐ Level 1 Assessment – Type A components subject to internal pressure.
 - ☐ Level 2 Assessment – Type A components subject to internal pressure and supplemental loads and Type B Class 1 components.

Required Data/Measurements for an FFS Assessment

L_H	edge-to-edge spacing between HIC damage and the nearest HIC or blister damage.
L_{Hs}	HIC-to-HIC or HIC-to-blister spacing in the longitudinal direction.
L_{msd}	spacing to nearest major structural discontinuity.
L_W	spacing to nearest weld joint.
s_1	HIC or blister dimension for HIC damage area 1 in the longitudinal direction.
s_2	HIC or blister dimension for HIC damage area 2 in the longitudinal direction.
c_1	HIC or blister dimension for HIC damage area 1 in the circumferential direction.
c_2	HIC or blister dimension for HIC damage area 2 in the circumferential direction.

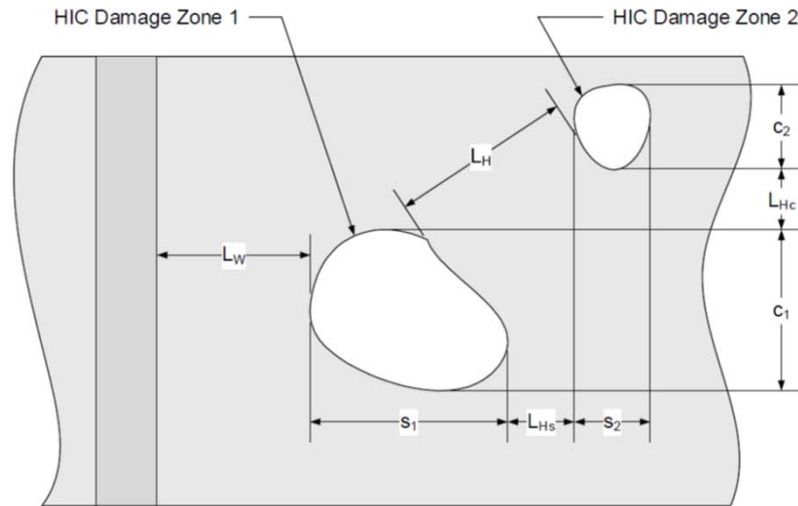


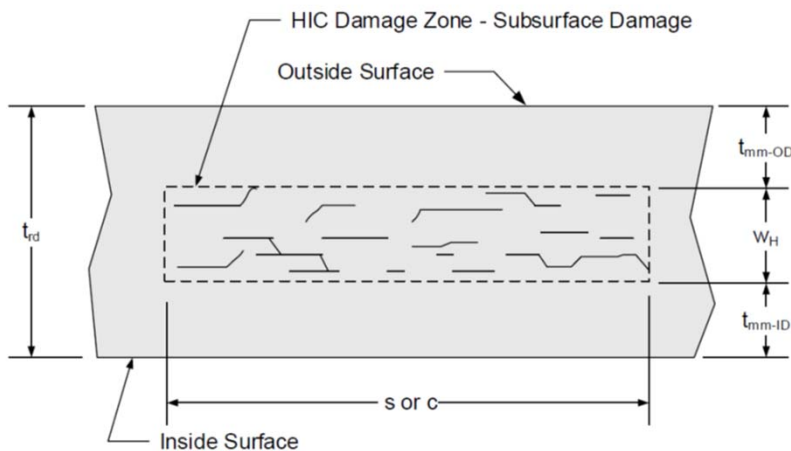
Table 7.1 – Size, Location, Condition, and Spacing for HIC Damage

Enter the data obtained from a field inspection on this form.					
Inspection Date: _____					
Equipment Identification: _____					
Equipment Type: _____ Pressure Vessel _____ Storage Tank _____ Piping Component					
Component Type & Location: _____					

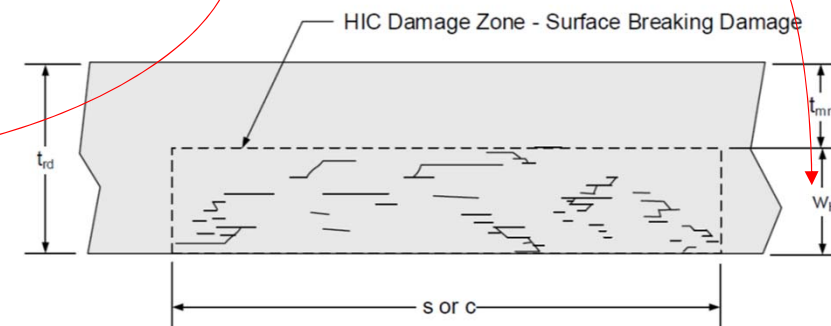
t_{nom} : _____					
LOSS: _____					
FCA: _____					
t_{rd} : _____					
Data Required for Level 1 and Level 2 Assessment					
HIC Identification					
Diameter s (1)					
Dimension c (1)					
Edge-To-Edge Spacing to Nearest HIC or Blister L_H (2)					
Minimum Measured Thickness to Internal Surface t_{mm-ID} (3)					
Minimum Measured Thickness to External Surface t_{mm-OD} (3)					
Minimum Measured Thickness; Total of Both Sides t_{mm} (3)					
Spacing to Nearest Weld Joint L_W (2)					
Spacing to Nearest Major Structural Discontinuity L_{msd}					
Notes:					
1. The HIC-to-HIC spacing may affect the size of the HIC damage to be used in the evaluation (see paragraph 7.3.3.1(i)).					
2. See Figure 7.3 .					
3. See Figure 7.2 .					

- t_{mm} minimum measured thickness of undamaged metal at the blister or HIC being evaluated, modified by the future corrosion allowance (FCA) as required.
- t_{mm-ID} minimum measured thickness of undamaged metal on the internal side of HIC damage, modified by the future corrosion allowance (FCA) as required.
- t_{mm-OD} minimum measured thickness of undamaged metal on the external side of HIC damage, modified by the future corrosion allowance (FCA) as required.
- t_{nom} nominal or furnished thickness of the component adjusted for mill under tolerance as applicable.
- t_{rd} uniform thickness away from the damage area established by thickness measurements at the time of the inspection.
- w_H thickness of HIC damage as measured in the through-thickness direction, modified by the future corrosion allowance (FCA) as required.

W_H ✓



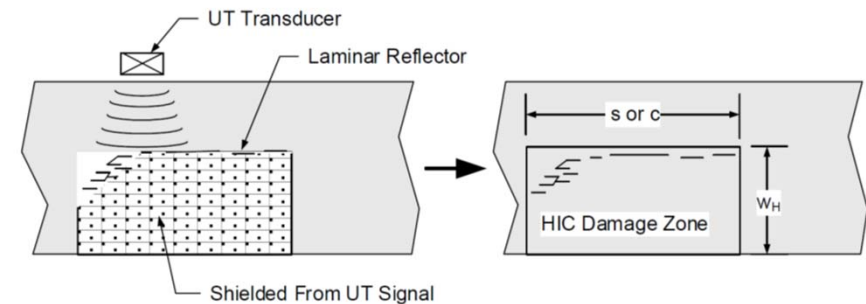
a) Typical Subsurface HIC Damage



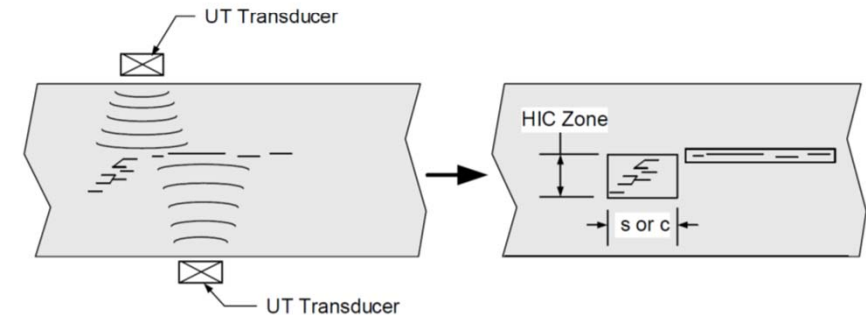
b) Typical Surface Breaking HIC Damage

Recommendations for Detection, Characterization, and Sizing

- ❑ HIC damage is a three-dimensional array of linear indications.
- ❑ Ultrasonic examination or other suitable techniques shall be used to detect HIC damage that is subsurface and to determine the subsurface dimensions of the HIC damage, including the **remaining undamaged thickness** at the HIC location.
- ❑ When HIC damage are present in the proximity of **welds**, **structural discontinuities**, or other **stress concentrating features**, the possibility of stress oriented hydrogen induced cracking (**SOHIC**) should be considered



Single Sided UT Exam; if HIC Damage is Found, Treat the Associated Area Shielded From UT Signal as Also Being HIC Damaged.



Two Sided UT Exam; Material Under Laminar Defect can be Interrogated. HIC Damage Size is Confirmed to be Limited.

Figure 7.10 – Characterization and Sizing of HIC Damage Zones Using Ultrasonic Examination

Assessment Techniques and Acceptance Criteria

Level 1: The Level 1 Assessments are limited to **Type A components**. The assessment procedures provide **screening criteria** to evaluate HIC damage, considering the damage from the perspective of **local metal loss**.

STEP 1- Determine the wall thickness to be used in the assessment.

$$t_c = t_{nom} - LOSS - FCA$$

STEP 2- Determine the information

- Spacing to nearest HIC or blister, LH
- Spacing to nearest weld, LW
- Spacing to nearest structural discontinuity, Lmsd
- HIC through thickness extent, WH
- Minimum ID remaining wall, tmm-ID
- Minimum OD remaining wall, tmm-OD
- Total minimum remaining wall, tmm
- Classify damage as subsurface or surface breaking
- Longitudinal dimension, S
- Circumferential dimension, C
- ☐ LH is greater or equal to 8tc

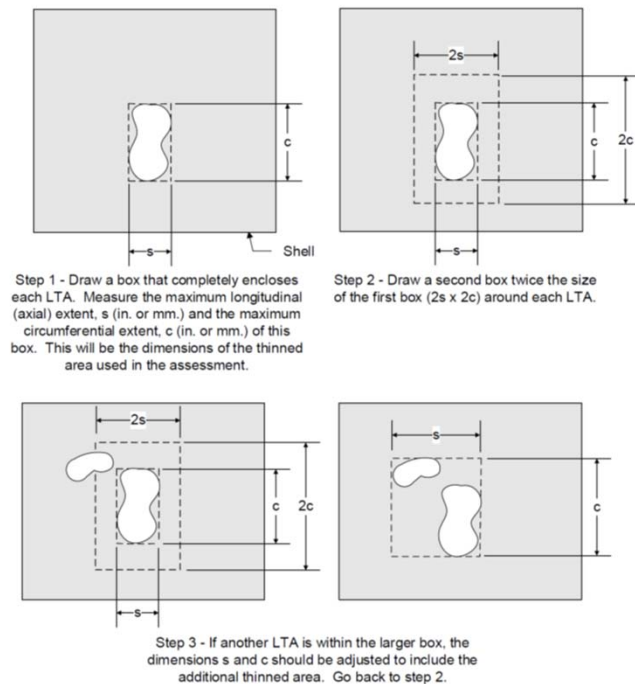


Figure 4.11 – Sizing of a Region with Multiple Areas of Metal Loss for an Assessment

STEP 3- If all the following requirements are satisfied, then proceed to STEP 4. Otherwise, the Level 1 Assessment is not satisfied.

- ✓ The planar dimensions of the HIC damage satisfy. $\left\{ \begin{array}{l} s \leq 0.60\sqrt{Dt_c} \\ c \leq 0.6\sqrt{Dt_c} \end{array} \right.$
- ✓ The through-thickness extent of the damage satisfies.
- ✓ The HIC damage is not surface breaking.
- ✓ The distance between the edge of the HIC damage and the nearest weld seam satisfies.
- ✓ The distance from the edge of the HIC damage to the nearest major structural discontinuity satisfies.

$$w_H \leq \min \left[\frac{t_c}{3}, 13 \text{ mm (0.5 in)} \right]$$

$$L_w > \max [2t_c, 25 \text{ mm (1.0 in)}]$$

$$L_{msd} \geq 1.8\sqrt{Dt_c}$$

Assessment Techniques and Acceptance Criteria

Level 2: The Level 2 Assessment procedure for determining the acceptability of HIC damage in Type A components subject to internal pressure and **supplemental loads** and Type B Class 1 components subject to internal pressure and supplemental loads.

STEP 1- Determine the information

- Spacing to nearest HIC or blister, LH
 - Spacing to nearest weld, LW
 - Spacing to nearest structural discontinuity, Lmsd
 - HIC through thickness extent, WH
 - Minimum ID remaining wall, tmm-ID
 - Minimum OD remaining wall, tmm-OD
 - Total minimum remaining wall, tmm
 - Classify damage as subsurface or surface breaking
 - Longitudinal dimension, S
 - Circumferential dimension, C
- ☐ LH is greater or equal to $8t_c$

STEP 2- Determine the wall thickness to be used in the assessment.

STEP 3- The distance between the edge of the HIC damage and the nearest weld seam satisfies.

STEP 4- The distance from the edge of the HIC damage to the nearest major structural discontinuity satisfies.

STEP 5- Classify the damage as either subsurface HIC or surface breaking HIC.

STEP 6- Determine the MAWP for the component.

STEP 7- Calculate the Remaining Strength Factor based on the type of HIC damage

❑ The Remaining Strength Factor for **surface-breaking HIC damage**

$$RSF = \frac{1 - \left[\frac{w_H \cdot D_H}{t_c} \right]}{1 - \frac{1}{M_t} \left[\frac{w_H \cdot D_H}{t_c} \right]} \quad \lambda = \frac{1.285s}{\sqrt{Dt_c}}$$

HIC damage shall be set equal to 80%, or $D_H = 0.80$.

❑ The Remaining Strength Factor for **subsurface HIC damage**

$$RSF = \frac{2L_R + s \left[1 - \left(\frac{w_H \cdot D_H}{t_c} \right) \right]}{2L_R + s}$$

$$L_R = \min \left[\frac{L_{Hs}}{2}, 8t_c \right]$$

STEP 8- If $RSF \geq RSFa$, then the longitudinal extent of the HIC damage satisfies.

STEP 9- For cylindrical shells, conical shells, and elbows, evaluate the circumferential extent of the HIC damage using an equivalent LTA.

$$c \leq 2s \left(\frac{E_c}{E_L} \right)$$

STEP 10-Determine whether a fracture assessment is required.

- ☐ The equipment remains in **hydrogen charging service**, and hydrogen charging has not been halted by means of a barrier coating, overlay, or process change.
- ☐ The HIC damage is classified as **surface-breaking**.
- ☐ The through-wall extent of the HIC damage satisfies. $w_H > \min \left[\frac{t_c}{3}, 13 \text{ mm } (0.5 \text{ in.}) \right]$

STEP 11- Evaluate the HIC damage as a crack-like flaw, two crack-like flaw assessments shall be performed, one for the longitudinal direction and one for the circumferential direction.

STEP 12- Confirm that further HIC damage has been either prevented or is limited to a known or verifiable rate by one or more of the following means. Otherwise, the Level 2 Assessment is not satisfied.

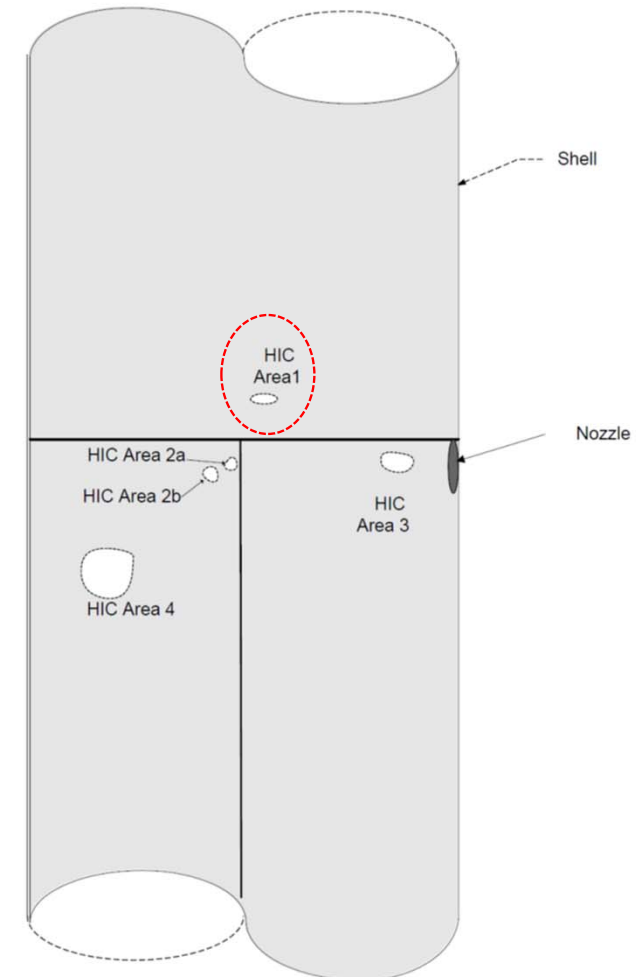
- ☐ Establishment of a **barrier coating**
- ☐ Use of **corrosion inhibitors** or other process chemicals that reduce the severity of hydrogen charging
- ☐ **Modification of process** or operating conditions to reduce the severity of hydrogen charging
- ☐ Use of devices that **monitor hydrogen** permeation through the equipment
- ☐ Review of historical records indicating that **HIC damage size and extent is stable** or progressing at a well-defined rate
- ☐ Monitoring of defects at an established interval to ensure **growth rates are within expected limits**

7.1 Example Problem 1

HIC damage has been discovered on a cylindrical pressure vessel. Both subsurface and surface breaking HIC damage are present. The vessel was constructed to the ASME B&PV Code, Section VIII, Division 1. Determine if the vessel is acceptable for continued operation fully pressurized at 50°F.

Vessel Data

• Material	=	SA-516 Grade70 Year 1984
• Design Conditions	=	300 <i>psig</i> @ 600 °F
• Inside Diameter	=	96 <i>in</i>
• Fabricated Thickness	=	1.25 <i>in</i>
• FCA	=	0.125 <i>in</i>
• Weld Joint Efficiency	=	0.85
• PWHT	=	Yes



Perform level 1 assessment on HIC area 1

STEP 1- Determine the wall thickness to be used in the assessment.

$$t_c = t_{nom} - LOSS - FCA = 1.25 - 0 - 0.125 = 1.125$$

STEP 2- Determine the information

- Spacing to nearest HIC or blister, $LH=20$ in
 - Spacing to nearest weld, $LW=10$ in
 - Spacing to nearest structural discontinuity, $Lmsd=50$ in
 - HIC through thickness extent, $WH=0.475$ in
 - Minimum ID remaining wall, $t_{mm-ID}=0.1$ in
 - Minimum OD remaining wall, $t_{mm-OD}=0.55$ in
 - Total minimum remaining wall, $t_{mm}=0.65$ in
 - Classify damage as subsurface or surface breaking
 - Longitudinal dimension, $S=3$ in
 - Circumferential dimension, $C=5$ in
- ☐ LH is greater or equal to $8t_c$

$$(L_H = 20.0 \text{ in}) \geq (8t_c = 9.0 \text{ in}) \quad \checkmark$$

Size, Location, Condition, and Spacing for HIC Damage
Enter the data obtained from a field inspection on this form.

Inspection Date: _____
 Equipment Identification: _____
 Equipment Type: ☒ Pressure Vessel ☐ Storage Tank ☐ Piping Component
 Component Type & Location: _____

t_{nom} : 1.25
 $LOSS$: _____
 FCA : 0.125
 t_{cl} : 1.25

Data Required for Level 1 and Level 2 Assessment					
HIC Identification	HIC Area 1	HIC Area 2a	HIC Area 2b	HIC Area 3	HIC Area 4
Diameter s (1)	3	2	1	3	7
Dimension c (1)	5	2	1	5.5	4.5
Edge-To-Edge Spacing To Nearest HIC or Blister L_H (2)	20	2	2	28.5	32
Minimum Measured Thickness to Internal Surface t_{mm-ID} (3)	0.1	0.0	0.45	0.2	0.25
Minimum Measured Thickness to External Surface t_{mm-OD} (3)	0.55	0.475	0.475	0.65	0.575
Minimum Measured Thickness ; Total of Both Sides t_{mm} (3)	0.65	0.475	0.925	0.85	0.825
Spacing To Nearest Weld Joint L_W (2)	10	1.5	6	9	28
Spacing To Nearest Major Structural Discontinuity L_{msd}	50	50	50	12	50
Depth of HIC damage W_H	0.475	0.65	0.2	0.275	0.3

Notes:
 1. The HIC-to-HIC spacing may affect the size of the HIC damage to be used in the evaluation (see paragraph 7.3.3.1.i.).
 2. See Figure 7.3.
 3. See Figure 7.2

STEP 3- If all the following requirements are satisfied, then proceed to STEP 4. Otherwise, the Level 1 Assessment is not satisfied.

- ✓ The planar dimensions of the HIC damage satisfy.

$$\left\{ \begin{array}{l} (s = 3.0 \text{ in}) \leq (0.6\sqrt{D \cdot t_c} = 6.243 \text{ in}) \quad \checkmark \\ (c = 5.0 \text{ in}) \leq (0.6\sqrt{D \cdot t_c} = 6.243 \text{ in}) \quad \checkmark \end{array} \right.$$
- ✓ The through-thickness extent of the damage satisfies.

$$(w_H = 0.475 \text{ in}) \leq \min \left[\left(\frac{t_c}{3} = 0.375 \text{ in} \right), 0.5 \text{ in} \right] \quad \times$$
- ✓ The HIC damage is not surface breaking.

$$(t_{mm-ID} = 0.1 \text{ in}) \geq (0.2t_c = 0.225 \text{ in}) \quad \times$$

$$(t_{mm-OD} = 0.55 \text{ in}) \geq (0.2t_c = 0.225 \text{ in}) \quad \checkmark$$
- ✓ The distance between the edge of the HIC damage and the nearest weld seam satisfies.

$$(L_w = 10.0 \text{ in}) > \max \left[(2t_c = 2.25 \text{ in}), 1.0 \text{ in} \right] \quad \checkmark$$
- ✓ The distance from the edge of the HIC damage to the nearest major structural discontinuity satisfies.

$$(L_{msd} = 50.0 \text{ in}) \geq (1.8\sqrt{D \cdot t_c} = 18.73 \text{ in}) \quad \checkmark$$

Perform level 2 assessment on HIC area 1

STEP 1- See level 1, STEP 1

STEP 2- See level 1, STEP 2

STEP 3- See level 1, STEP 3

STEP 4- See level 1, STEP 3

STEP 5- Damage is classified as surface breaking

$$w_H = w_H + \min[t_{mm-ID}, t_{mm-OD}]$$

$$w_H = 0.475 + \min[0.1, 0.55] = 0.475 + 0.1 = 0.575 \text{ in}$$

STEP 6- Determine the MAWP of the component

$$MAWP = \frac{SEt_c}{R + 0.6t_c} = \frac{(17500)(1.0)(1.125)}{48.125 + 0.6(1.125)} = 403 \text{ psi}$$

STEP 7- Calculate the RSF based on surface breaking HIC damage

$$RSF = \frac{1 - \left[\frac{w_H \cdot D_H}{t_c} \right]}{1 - \frac{1}{M_t} \left[\frac{w_H \cdot D_H}{t_c} \right]} = \frac{1 - \left[\frac{(0.575)(0.8)}{1.125} \right]}{1 - \frac{1}{1.0311} \left[\frac{(0.575)(0.8)}{1.125} \right]} = 0.980$$

$$\lambda = \frac{1.285s}{\sqrt{Dt_c}} = \frac{1.285(3.0)}{\sqrt{(96.25)(1.125)}} = 0.3705 \quad M_t = 1.0311$$

STEP 8- Evaluate the longitudinal extent of the flaw

$$(RSF = 0.980) \geq (RSF_a = 0.9) \quad \checkmark$$

STEP 9- Evaluate the longitudinal extent of the flaw

$$c \leq 2s \left(\frac{E_C}{E_L} \right) \rightarrow 5 \leq 2 \times 3 \times \left(\frac{0.85}{0.85} \right) \quad \checkmark$$

The Level 2 Assessment Criteria are satisfied.

STEP 10- Determine whether a fracture assessment is required

- ☐ The equipment remains in **hydrogen charging service**. 
- ☐ The HIC damage is classified as **surface-breaking**. 
- ☐ The through-wall extent of the HIC damage satisfies.

$$(w_H = 0.575 \text{ in}) \geq \min \left[\left(\frac{t_c}{3} = 0.375 \text{ in} \right), 0.5 \text{ in} \right] \quad \checkmark$$

The equipment is fit for continued operation at design stress and temperature pending the outcome of a fracture assessment following procedures listed in Part 9 and the outcome of the assessments of other damaged areas.