Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571 Jarbas Cabral Fagundes; Braskem

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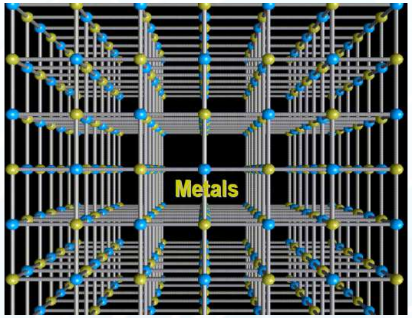

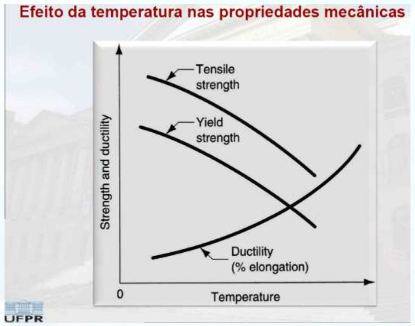

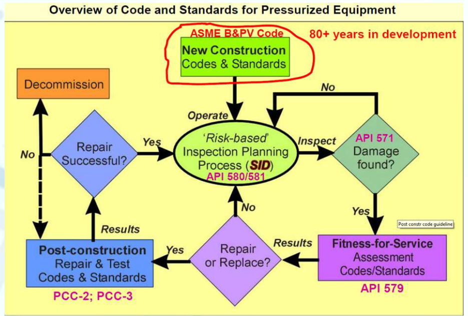

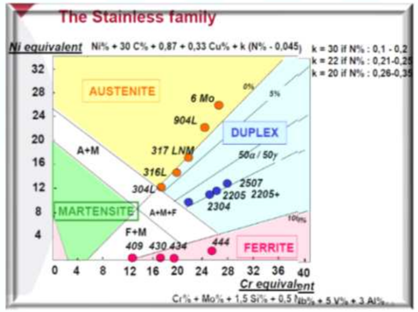

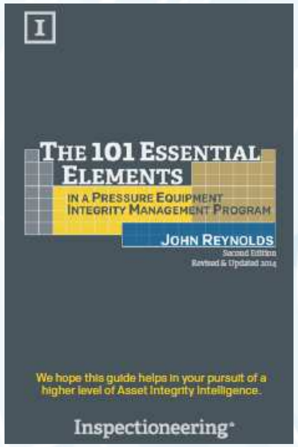

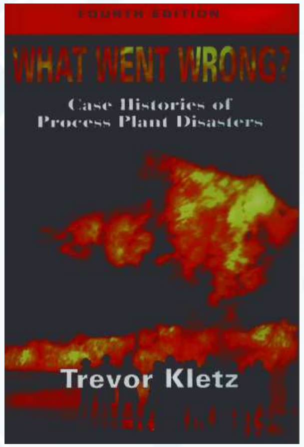

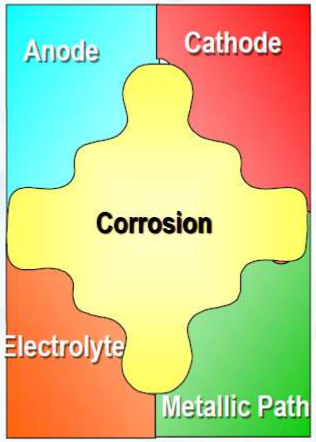

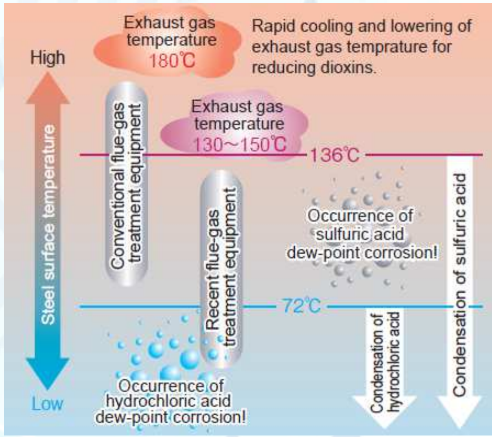

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Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

Damage Mechanisms Affecting Fixed Equipment in the Refining Industry

API RECOMMENDED PRACTICE 571
SECOND EDITION, APRIL 2011

Downstream Segment

energy API
AMERICAN PETROLEUM INSTITUTE

Damage Mechanisms Affecting Fixed Equipment in the Refining Industry

RECOMMENDED PRACTICE 571
FIRST EDITION, DECEMBER 2003

Damage Mechanisms Affecting Fixed Equipment in the Refining Industry

RECOMMENDED PRACTICE 571
SECOND EDITION, XXXX 2009

Damage Mechanisms Affecting Fixed Equipment in the Refining Industry

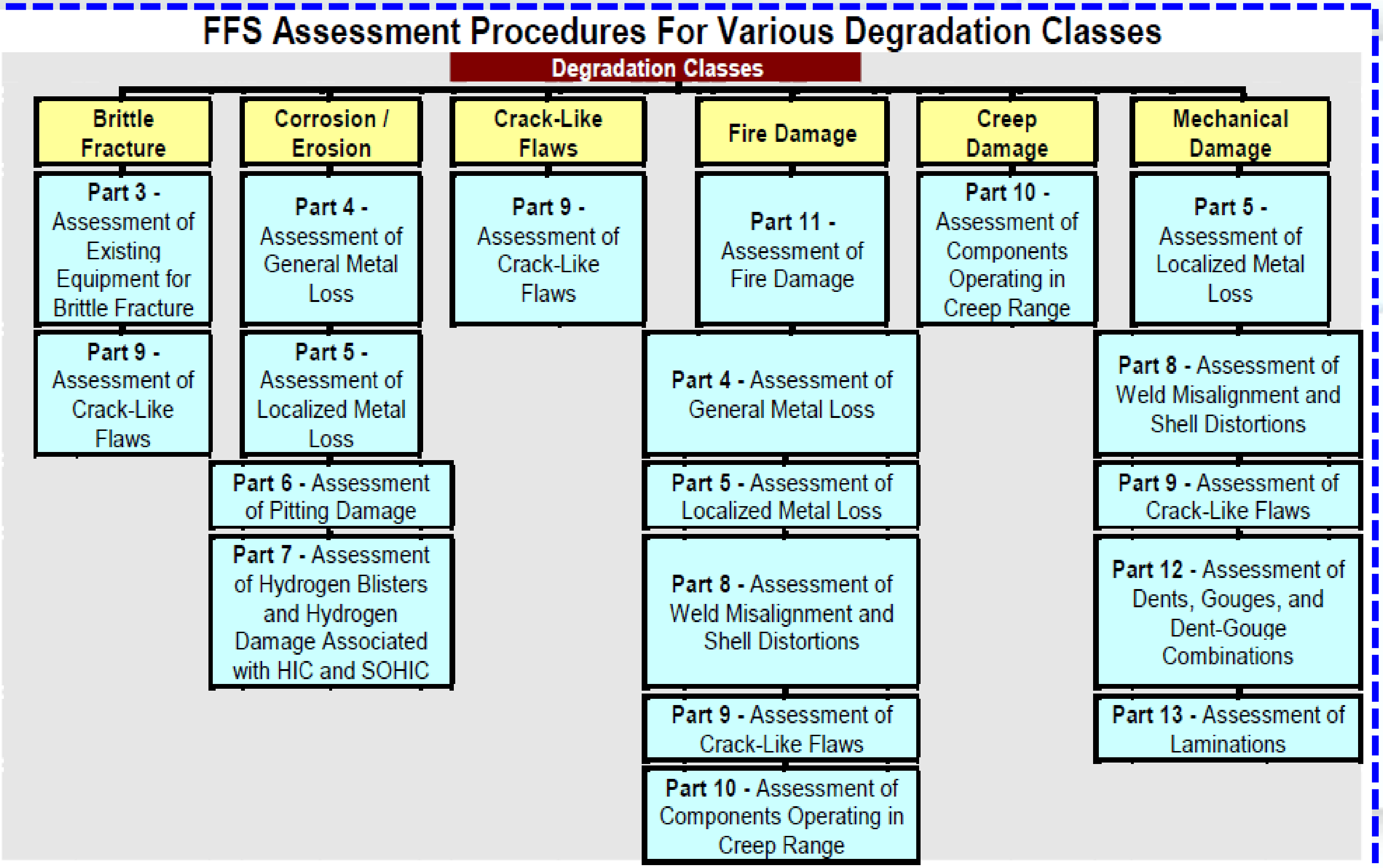
API RECOMMENDED PRACTICE 571
SECOND EDITION, APRIL 2011

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

What is it intended for?

Provides basic information about damage that may occur in Process Unit Equipment. It aims to complement technical support for risk-based inspection (API RP 580 e API RP 581), using the same methodologie Fitness-for-service (API RP 579/ASME FFS-1), developed in recent years by the API to manage the integrity of equipment . API 571 is recognized as an excellent tool for operation, inspection and maintenance time. This best practice covers 66 damage mechanisms.

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571



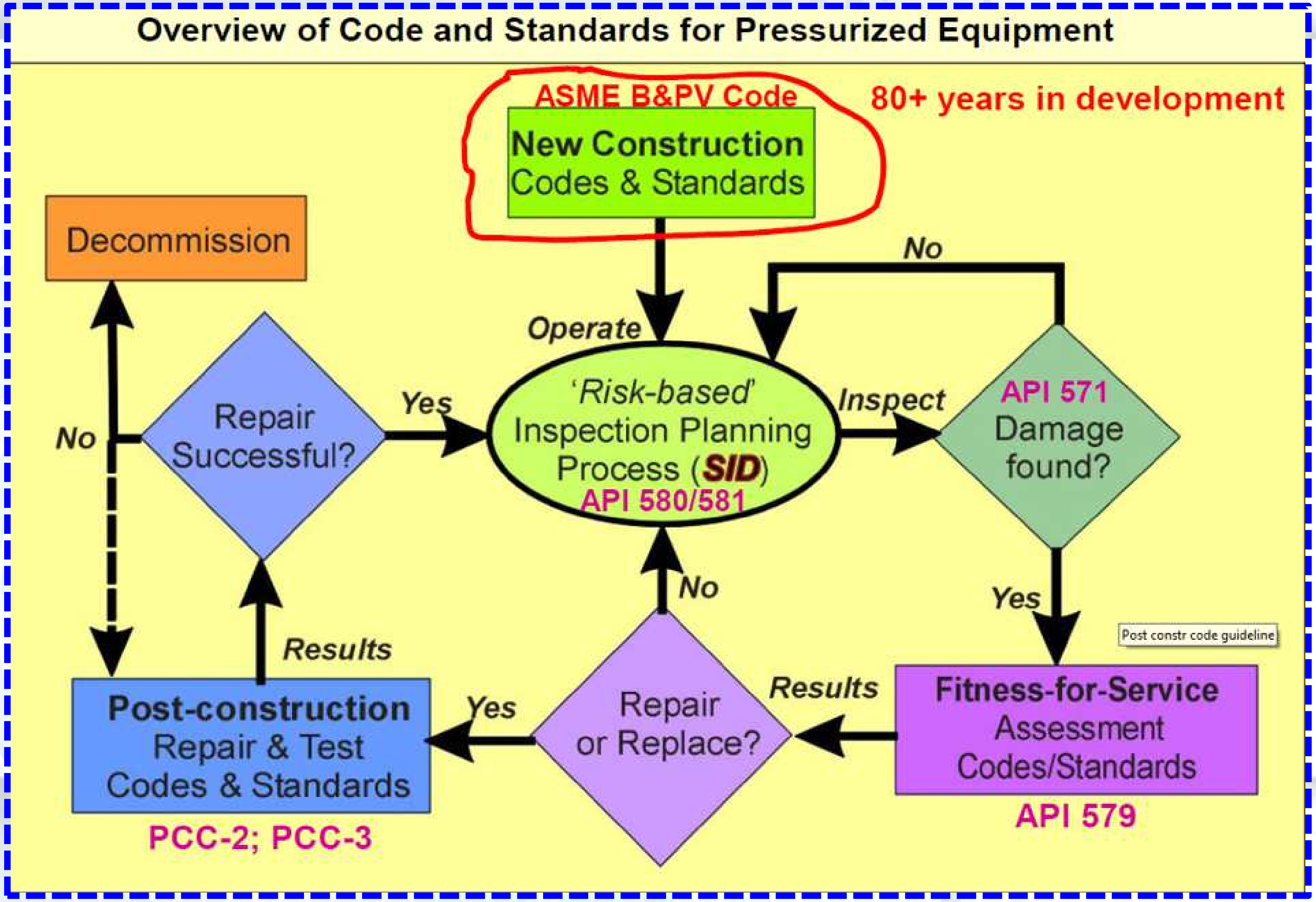
Fluxograma 1 - Classes de Degradação do API 579 / ASME FFS-1

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

Inspection Technique	Thinning	Surface Connected Cracking	Subsurface Cracking	Microfissuring / Microvoid Formation	Metallurgical Changes	Dimensional Changes	Blistering
Visual Examination	1 – 3	2 – 3	X	X	X	1 – 3	1 – 3
Ultrasonic Straight Beam	1 – 3	3 – X	3 – X	2 – 3	X	X	1 – 2
Ultrasonic Shear Wave	X	1 – 2	1 – 2	2 – 3	X	X	X
Fluorescent Magnetic Particle	X	1 – 2	3 – X	X	X	X	X
Dye Penetrant	X	1 – 3	X	X	X	X	X
Acoustic Emission	X	1 – 3	1 – 3	3 – X	X	X	3 – X
Eddy Current	1 – 2	1 – 2	1 – 2	3 – X	X	X	X
Flux Leakage	1 – 2	X	X	X	X	X	X
Radiography	1 – 3	3 – X	3 – X	X	X	1 – 2	X
Dimensional Measurements	1 – 3	X	X	X	X	1 – 2	X
Metallography	X	2 - 3	2 – 3	2 - 3	1 - 2	X	X

1 – Highly effective 2 – Moderately effective 3 – Possibly effective X – Not normally used

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571



Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

1.2 Escopo: Esta Prática Recomendada fornece orientações gerais sobre os Mecanismos de Danos MAIS PROVÁVEIS que afetam os materiais e ligas comuns usados nas Indústrias de Refino e Petroquímica e tem objetivo de introduzir o conceito de deterioração oacsioanada pelo serviço exercido, bem como no Modo de Falha Atuante. São Diretrizes que podem ser utilizadas pelo pessoal de inspeção (SPIEs), Confiabilidade, Integridade Mecânica, etc, para auxiliar na Identificação de Causas prováveis de Danos, no desenvolvimento de Estratégias de Inspeção, bem como identificar Programas de Monitoramento que garantam a Integridade dos Equipamentos.

- **provides general guidance on damage mechanisms.**
- **has the objective of introducing the concept of deterioration caused by the service performed and the active failure mode.**
- **API 571 is recognized as an excellent tool for operation, inspection and maintenance time.**
- **aims to identify monitoring programs that ensure the integrity of the equipment**

Um resumo para cada Mecanismo de Dano Atuante fornece as informações fundamentais para uma Avaliação a luz do API 579-1 / ASME FFS-1 ou mesmo para um Estudo de RBI-Risk Based Inspection em conformidade com o API RP 580.

A summary for each active damage mechanism provides the fundamental information for evaluation and inspection based on recommended practice.

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

Mecanismos de Danos

Seção 4.0: groups the Damage Mechanisms that are common to a variety of Industries, including Refineries and Petrochemicals.

Seção 5.0: groups the Damage Mechanisms that are Specific to the Refining and Petrochemical Industries.

Seção 5.2: the Process Flow diagrams are provided to help the user determine where some of the Significant Damage Mechanisms are commonly found.

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

SECTION 3 - DEFINITION OF TERMS AND ABBREVIATIONS – 3.1 Terms

Materiais envolvidos nessa Prática Recomendada

1.5 Definições e Terminologias	
Na Seção 3.0, encontraremos um Glossário de Terminologias e Abreviações que ajudará muito o usuário.	
Termos:	18
Símbolos e Abreviações:	70

3.1.2 Austenitic stainless steels – the 300 Series stainless steels including Types 304, 304L, 304H, 309, 310, 316, 316L, 316H, 321, 321H, 347, and 347H. The "L" and "H" suffixes refer to controlled ranges of low and high carbon content, respectively. These alloys are characterized by an austenitic structure.

3.1.3 Carbon steel – steels that do not have alloying elements intentionally added. However, there may be small amounts of elements permitted by specifications such as SA 516 and SA 106, for example that can affect corrosion resistance, hardness after welding, and toughness. Elements which may be found in small quantities include Cr, Ni, Mo, Cu, S, Si, P, Al, V and B.

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

SECTION 3 - DEFINITION OF TERMS AND ABBREVIATIONS – 3.2 Terms
Materiais envolvidos nessa Prática Recomendada

Section 3.0 - Definition of Terms and Abbreviations - 3.2 Simbols and Abbreviations		
3.2.1	ACFM	Alternating current field measurement.
3.2.2	ASCC	Alkaline stress corrosion cracking.
3.2.3	ACSCC	Alkaline carbonate stress corrosion cracking.
3.2.4	AE	Acoustic emission.
3.2.5	AET	Acoustic emission testing.
3.2.6	AGO	Atmospheric gas oil.
3.2.7	AUBT	Automated ultrasonic backscatter testing.
3.2.8	BFW	Boiler feed water.
3.2.9	C2	Chemical symbol referring to ethane or ethylene.
3.2.10	C3	Chemical symbol referring to propane or propylene.
3.2.11	C4	Chemical symbol referring to butane or butylenes.
3.2.12	CAT	Catalyst or catalytic.
3.2.13	CDU	Crude distillation unit.
3.2.14	CH4	Methane.
3.2.15	CO	Carbon monoxide.
3.2.16	CO2	Carbon dioxide.
3.2.17	CVN	Charpy v-notch.
3.2.18	CW	Cooling water.
3.2.19	DIB	Deisobutanizer.
3.2.20	DNB	Departure from Nucleate Boiling

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

GENERAL DAMAGE MECHANISMS – ALL INDUSTRIES

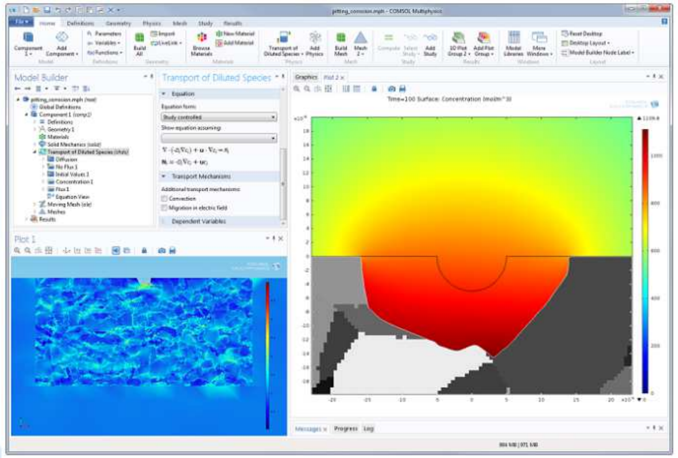
DM	4.2	Mechancial and Metallurgical Failure Mechanisms
1	4.2.1	Graphitization
2	4.2.2	Softening (Spheroidization)
3	4.2.3	Temper Embrittlement
4	4.2.4	Strain Aging
5	4.2.5	885 ºF (475ºC) Embrittlement
6	4.2.6	Sigma Phase Embrittlement
7	4.2.7	Brittle fracture
8	4.2.8	Creep and Stress Rupture
9	4.2.9	Thermal Fatigue
10	4.2.10	Short Term Overheating - Stress rupture
11	4.2.11	Steam Blanketing
12	4.2.12	Dissimilar Metal Weld (DMW) Cracking
13	4.2.13	Thermal Shock
14	4.2.14	Erosion / Erosion - Corrosion
15	4.2.15	Cavitation
16	4.2.16	Mechancial Fatigue
17	4.2.17	Vibration-Induced Fatigue
18	4.2.18	Refractory Degradation
19	4.2.19	Reheat Cracking
20	4.2.20	Gaseous Oxygen-Enhanced Ignition and Combustion

DM	4.3	Uniform or Localized Loss of Thickness
21	4.3.1	Galvanic Corrosion
22	4.3.2	Atmospheric Corrosion
23	4.3.3	Corrosion Under Insulation (CUI)
24	4.3.4	Cooling Water Corrosion
25	4.3.5	Boiler Water Condensate Corrosion
26	4.3.6	CO2 Corrosion
27	4.3.7	Flue-Gas Dew-Point Corrosion
28	4.3.8	Microbiologically Induced Corrosion (MIC)
29	4.3.9	Soil Corrosion
30	4.3.10	Caustic Corrosion
31	4.3.11	Dealloying
32	4.3.12	Graphitic Corrosion

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

GENERAL DAMAGE MECHANISMS – ALL INDUSTRIES

DM	4.4	High Temperature Corrosion [> 400ºF (204ºC)]
33	4.4.1	Oxidation
34	4.4.2	Sulfidation
35	4.4.3	Carburization
36	4.4.4	Descaeburization
37	4.4.5	Metal Dusting
38	4.4.6	Fuel Ash Corrosion
39	4.4.7	Nitriding



DM	4.5	Environment - Assisted Cracking
40	4.5.1	Chloride Stress Corrosion Cracking (ClSCC)
41	4.5.2	Corrosion Fatigue
42	4.5.3	Caustic Stress Corrosion Cracking (Caustic Embrittlement)
43	4.5.4	Ammonia Stress Corrosion Cracking
44	4.5.5	Liquid Metal Embrittlement (LME)
45	4.5.6	Hydrogen Embrittlement (HE)
46	4.5.7	Ethanol Stress Corrosion Cracking (SCC)
47	4.5.8	Sulfate Stress Corrosion Cracking

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

DM	5.1.1.	Uniform or Lozalized Loss in Thickness Phenomena
48	5.1.1.1	Amine Corrosion
49	5.1.1.2	Ammonium Bisulfide Corrosion (Alkaline Sour Water)
50	5.1.1.3	Ammonium Chloride Corrosion
51	5.1.1.4	Hydrochloric Acid (HCl) Corrosion
52	5.1.1.5	Higt Temp H2/H2S Corrosion
53	5.1.1.6	Hydrofluoric (HF) Acid Corrosion
54	5.1.1.7	Naphtenic Acid Corrosin (NAC)
55	5.1.1.8	Phenol (Carbolic Acid) Corrosion
56	5.1.1.9	Phosphoric Acid Corrosion
57	5.1.1.10	Sour Water Corrosion (Acidic)
58	5.1.1.11	Sulphuric Acid Corrosion
59	5.1.1.12	Aqueous Organic Acid Corrosion

DM	5.1.2	Environment-Assisted Cracking
60	5.1.2.1	Polythionic Acid Stress Corrosion Cracking (PASCC)
61	5.1.2.2	Amine Stress Corrosion Cracking
62	5.1.2.3	Wet H2S Damage (Blistering/HIC/SOHIC/SSC)
63	5.1.2.4	Hydrogen Stress Cracking - HF
64	5.1.2.5	Carbonate Stress Corrosion Cracking (ACSCC)

DM	5.1.3	Other Mechanisms
65	5.1.3.1	High Temperature Hydrogen Attack (HTHA)
66	5.1.3.2	Titanium Hydriding

Mechanical Integrity Program – Approach about Damage Mechanisms in according API RP 571

API RP 571 - Table 5-4 - Key to Damage Mechanisms

DM	Damage Mechanism	Item do Corpo do API	DM	Damage Mechanism	Item do Corpo do API
1	Sulfidation	4.4.2	34	Softening (Spheroidization)	4.2.2
2	Wet H2S Damage (Blistering HIC SOHIC SS	5.1.2.3	35	Reheat Cracking	4.2.19
3	Creep / Stress Rupture	4.2.8	36	Sulfuric Acid Corrosion	5.1.1.11
4	High Temperatue H2/H2S Corrosion	5.1.1.5	37	Hydrofluoric Acid Corrosion	5.1.1.6
5	Polythionic Acid Corrosion	5.1.2.1	38	Flue Gas Dew Point Corrosion	4.3.7
6	Naphtenic Acid Corrosion	5.1.1.7	39	Dissimilar Metal Weld (DMW) Cracking	4.2.12
7	Ammonium Bilsulfide Corrosion	5.1.1.2	40	Hydrogen Stress Cracking in HF	5.1.2.4
8	Ammonium Chloride Corrosion	5.1.1.3	41	Dealloying (Dezincification / Denickelification)	4.3.11
9	HCL Corrosion	5.1.1.4	42	CO2 Corrosion	4.3.6
10	High Temperature Hydrogen Attack	5.1.3.1	43	Corrosion Fatigue	4.5.2
11	Oxidation	4.4.1	44	Fuel Ash Corrosion	4.4.6
12	Thermal Fatigue	4.2.9	45	Amine Corrosion	5.1.1.1
13	Sour Water Corrosion (acid)	5.1.1.10	46	Corrosion Under Insulation (CUI)	4.3.3
14	Refractory Degradation	4.2.18	47	Atmospheric Corrosion	4.3.2
15	Graphitization	4.2.1	48	Ammonia Stress corrosion Cracking	4.5.4
16	Temper Embrittlement	4.2.3	49	Cooling Water Corrosion	4.3.4
17	Descarburization	4.4.4	50	Boiler Water / Condensate Corrosion	4.3.5
18	Caustic Cracking	4.5.3	51	Microbiologically Induced Corroion (MIC)	4.3.8
19	Caustic Corrosion	4.3.10	52	Liquid Metal Embrittlement	4.5.5
20	Erosion / Erosion-Corrosion	4.2.14	53	Galvanic Corrosion	4.3.1
21	Carbonate SCC	5.1.2.5	54	Mechancial Fatigue	4.2.16
22	Amine Cracking	5.1.2.2	55	Nitirding	4.4.7
23	Chloride Stress Corrosion Cracking	4.5.1	56	Vibration-Induced Fatigue	4.2.17
24	Carburization	4.4.3	57	Titanium Hydriding	5.1.3.2
25	Hydrogen Embrittlement	4.5.6	58	Soil Corrosion	4.3.9
26	Steam Blanketing	4.2.11	59	Metal Dusting	4.4.5
27	Thermal Shock	4.2.13	60	Strain Aging	4.2.4
28	Cavitation	4.2.15	61	Sulfate Stress Corrosion Cracking	4.5.8
29	Graphitic Corrosion (see Dealloying)	4.3.12	62	Phosphoric Acid Corrosion	5.1.1.9
30	Short Term Overheating - Stress Rupture	4.2.10	63	Phenol (carbolic acid) Corrosion	5.1.1.8
31	Brittle Fracture	4.2.7	64	Ethanol Stress Corrosion Cracking	4.5.7
32	Sigma Phase / Chi Embrittlement	4.2.6	65	Oxygen-Enchanced Induced and Combustion	4.2.20
33	885°F (475°C) Embrittlement	4.2.5	66	Organic Acid Corrosion of Distillation Tower Overhead Systems	5.1.1.12

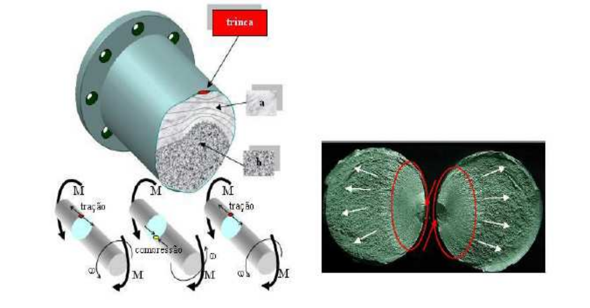
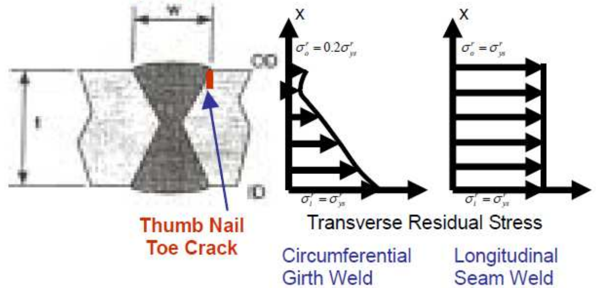


Figura 09.1 Fratura de um eixo que falhou por fadiga. A trinca iniciou-se na superfície do eixo.

PIPE WELDS (t=1")



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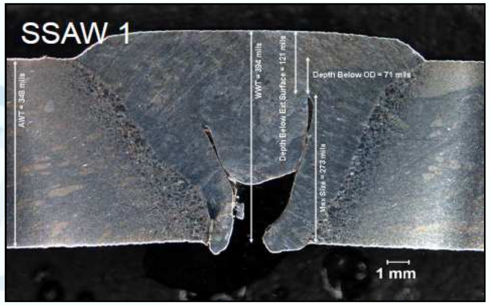
4.2.7 Brittle Fracture

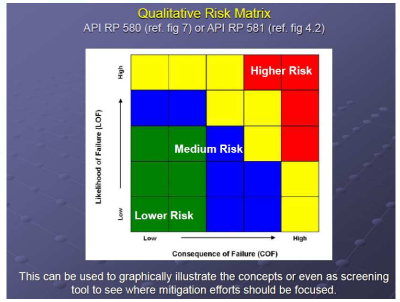
4.2.7.1 Description of Damage

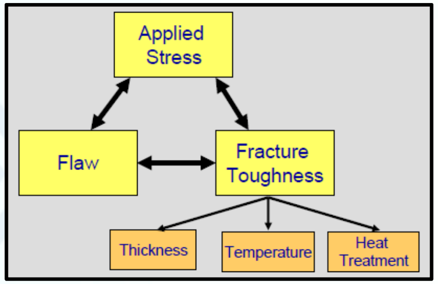
Brittle fracture is the sudden rapid fracture under stress (residual or applied) where the material exhibits little or no evidence of ductility or plastic deformation.

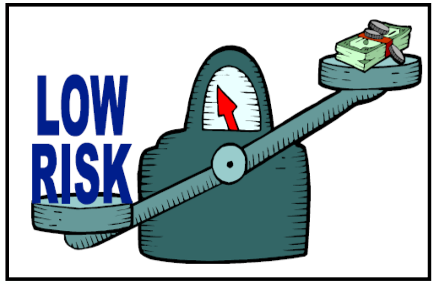
4.2.7.2 Affected Materials

Carbon steels and low alloy steels are of prime concern, particularly older steels. 400 Series SS are also susceptible.









Factors Affecting Material Toughness

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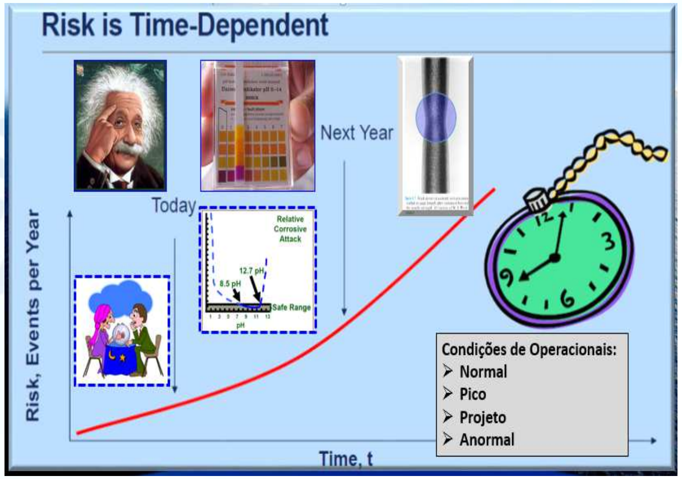
4.2.7.3 Critical Factors

For a material containing a flaw, brittle fracture can occur. Following are three important factors:

1) The Material fracture toughness (resistance to crack like flaws) as measured in a Charpy impact test;
2) The size, shape and stress concentration effect of a flaw;
3) The amount of residual and applied stresses on the flaw.



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4.2.7.4 Affected Units or Equipment

a) Equipment manufactured to the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, prior to the December 1987 Addenda, were made with limited restrictions on notch toughness for vessels operating at cold temperatures. However, this does not mean that all vessels fabricated prior to this date will be subject to brittle fracture. Many designers specified supplemental impact tests on equipment that was intended to be in cold service.

b) Equipment made to the same code after this date were subject to the requirements of UCS 66 (impact exemption curves).

c) Most processes run at elevated temperature so the main concern is for brittle fracture during startup, shutdown, or hydrotest/tightness testing. Thick wall equipment on any unit should be considered.

4.2.7.4 Affected Units or Equipment

d) Brittle fracture can also occur during an autorefrigeration event in units processing light hydrocarbons such as methane, ethane/ethylene, propane/propylene, or butane. **This includes alkylation units, olefin units and polymer plants (polyethylene and polypropylene). Storage bullets/spheres for light hydrocarbons may also be susceptible.**

e) Brittle fracture can occur during ambient temperature hydrotesting due to high stresses and low toughness at the testing temperature.

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4.2.7.5 Appearance or Morphology of Damage

a) Cracks will typically be straight, non-branching, and largely devoid of any associated plastic deformation (although fine shear lips may be found along the free edge of the fracture, or localized necking around the crack **(Figure 4-12 to Figure 4-16).**

b) Microscopically, the fracture surface will be composed largely of cleavage, with limited intergranular **Figure 4-16 – Classic example of brittle fracture that occurred during hydrotest** cracking and very little microvoid coalescence.

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4.2.7.6 Prevention / Mitigation

d) Some reduction in the likelihood of a brittle fracture may be achieved by:

1) Performing a **Post Weld Heat Treatment (PWHT)** on the vessel if it was not originally done during manufacturing; or if the vessel has been weld repaired/modified while in service without the subsequent PWHT.

2) Perform a "warm" pre-stress hydrotest followed by a lower temperature hydrotest to extend the **Minimum Safe Operating Temperature (MSOT)** envelope.

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4.2.7.7 Inspection and Monitoring

a) Inspection is not normally used to mitigate brittle fracture.

b) Susceptible vessels should be inspected for pre-existing flaws/defects.

4.2.7.8 Related Mechanisms

Temper embrittlement (see 4.2.3), strain age embrittlement (see 4.2.4), 885ºF (475ºC) embrittlement (see 4.2.5), titanium hydriding (see 5.1.3.2) and sigma embrittlement (see 4.2.6).

4.2.7.9 References

1. API 579-1/ASME FFS-1 2007 *Fitness-For-Service*, American Petroleum Institute, Washington, D.C., 2007

2. Jeffery A. Smith and Stanley T. Rolfe, "The Effect of Crack Depth (a) and Crack-Depth to Width Ratio (a/W) on the Fracture Toughness of A533-B Steel," WRC Bulletin 418, Welding Research Council, Shaker Heights, OH.

3. British Standard 7910, Guidance on Methods for Assessing the Acceptability of Flaws in Fusion Welded Structures, British Standards Institution, London, UK.

4. ASME Boiler and Pressure Vessel Code, Section III, Division I, Rules for Construction of Nuclear Power Plant Components ASME, New York, N.Y.

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Figure 4-15 – Brittle Fracture of vessel shell during hydrotest.

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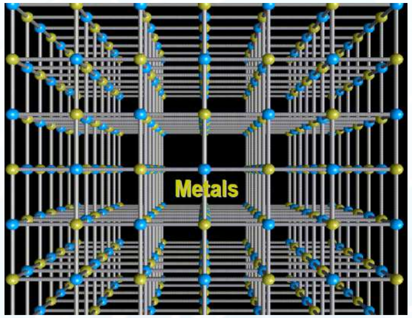

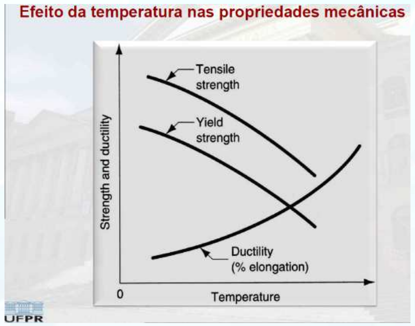

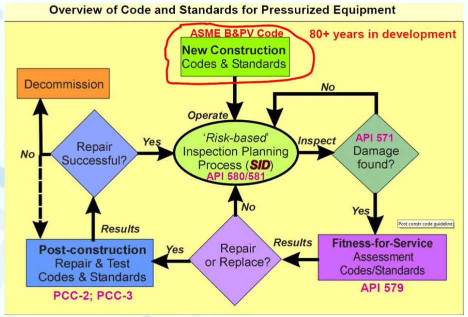

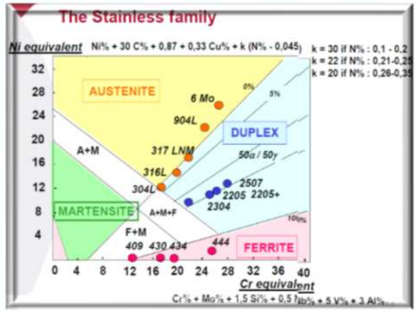

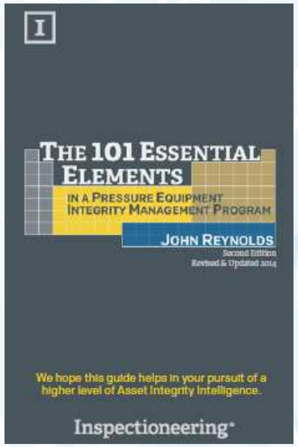

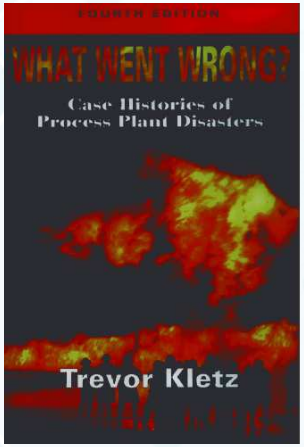

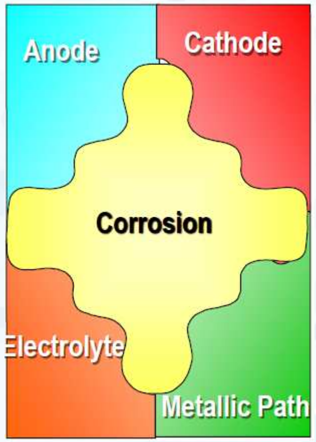

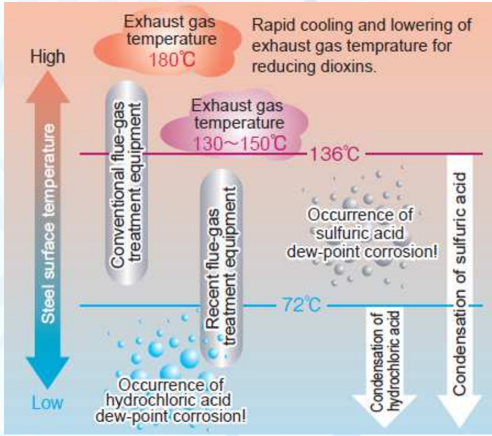

Thank you!

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