FÓRUM INTEGRIDADE DE EQUIPAMENTOS QUE TRABALHAM EM ALTA TEMPERATURA
01/SETEMBRO/2016

INCOLOY 800HT

Envelhecimento de Tubulação Operando em Altas Temperaturas

UNIB-RS

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Rio de Janeiro – 01 de Setembro de 2016

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IBP – Forum Integridade de Equipamentos que Trabalham em Alta Temperatura
Incoloy 800HT – Envelhecimento de Tubulação

Braskem

ibp

FÓRUM INTEGRIDADE DE EQUIPAMENTOS QUE TRABALHAM EM ALTA TEMPERATURA
01/SETEMBRO/2016

Programação

08:30 | Abertura

Roberto Caldas - Diretor de Pesquisa, Desenvolvimento e Inovação | CEPEL ELETROBRAS

Francini Ferreira | Gerente Executiva de Gestão do Conhecimento - IBP

08:45| New technologies and solutions for creep testing in metals

Christof Ditschuneit | Zwick Roell

09:45| Monitoramento online como Ferramenta para AIE

Bruno Reis Cardoso | Eletrobrás Cepel

Carlos Frederrico Trotta Matt | Eletrobrás Cepel

Fernanda Martins | Eletrobrás Cepel

10:45 | Coffee Break

11:00| Challenging strain measurement at high temperatures

Christof Ditschuneit | Zwick Roell

12:00| Cuidados na avaliação de vida à fluência de tubos de fornos

Laudemiro Nogueira Júnior | CENPES/Petrobras

12:40| Almoço

14:00| Avaliação de Integridade de Caldeiras de Grande Porte

Tito Luiz da Silveira | TSEC

14:40| Incoloy 800HT – envelhecimento de tubulação operando em altas temperaturas

Luis Carlos Greggianin | Braskem

15:20| Mesa Redonda

Carlos Bruno Eckstein | CENPES Petrobras

Luiz Henrique de Almeida | COPPE/UFRJ

Heloisa Cunha Furtado | CEPEL Eletrobras

Ricardo Barbosa Caldeira | ISQ Brasil

Local: CEPEL ELETROBRAS
Av. Horácio Macedo 354, Cidade Universitária
Ilha do Fundão, Rio de Janeiro - RJ

Sinopse

- Objetivo, processo e equipamentos
- Os Danos: Tubulação projeto antigo e novo
- Os Materiais: INCOLOY 800HT
- Inspeção – Mecanismo de Dano
- Reparos – soldagem
- Acompanhamento com Emissão Acústica
- Recomendações

Objetivo, Processo e Equipamentos

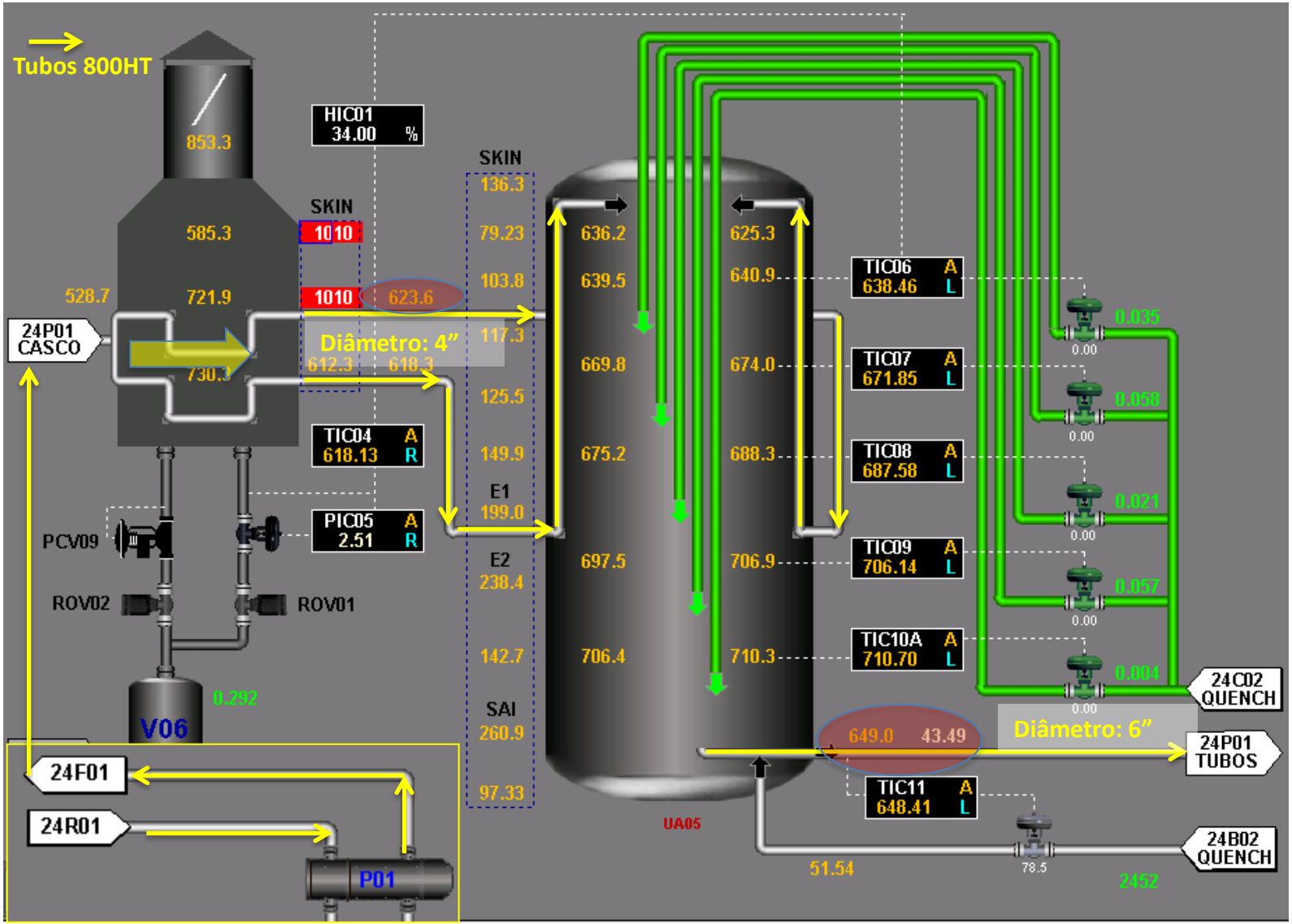
Apresentar os danos ocorridos em tubulação de interligação entre os equipamentos: Forno + Reator + Trocador e as medidas corretivas

Material: ASTM SB-407 UNS N08811 [*INCOLOY 800HT*]

Unidade 24 – Hidrodealquilação de Tolueno

Função: Conversão de Aromáticos (Tolueno, Xileno e C9) para Benzeno

Carga líquida de 13 t/h é pré-aquecida em trocador carga/efluente antes de entrar em forno e segue para reator onde recebe corrente de H2


Tubos 800HT
HIC01
34.00 %
853.3
SKIN
585.3
1010
1010
623.6
528.7
721.9
730.3
24P01
CASCO
Diâmetro: 4"
612.3
618.3
TIC04 A
618.13 R
PIC05 A
2.51 R
PCV09
ROV02
ROV01
0.292
V06
24F01
24R01
P01
SKIN
136.3
79.23
103.8
117.3
125.5
149.9
E1
199.0
E2
238.4
142.7
SAI
260.9
97.33
636.2
639.5
669.8
675.2
697.5
706.4
625.3
640.9
674.0
688.3
706.9
710.3
TIC06 A
638.46 L
TIC07 A
671.85 L
TIC08 A
687.58 L
TIC09 A
706.14 L
TIC10A A
710.70 L
0.035
0.00
0.058
0.00
0.021
0.00
0.057
0.00
0.004
0.00
24C02
QUENCH
649.0 43.49
Diâmetro: 6"
24P01
TUBOS
TIC11 A
648.41 L
UA05
51.54
78.5
24B02
QUENCH
2452


Reator
Forno
Trocador

Projetista: HRI [Hydrocarbon Research Inc]	**Projeto**	**Operação**
Pressão [kgf/cm2]	52,7	40 - 43
Temperatura [ºC]	677	640-660

Materiais	**Tubos**	**Solda**
1979 Projeto Original	SA-312 TP 316 UNS S31600	AWS 5.9 ER 316 UNS S31680
1993 Projeto Revisado (Atual)	SB-407 UNS N08811 [*INCOLOY 800HT*]	AWS 5.14 ERNiCrCoMo-1 UNS N06617 [*INCONEL 617*]

Diâmetro [pol]	**4**	**6**
Espessura [mm]	13,5	18,3

Os Danos: Tubulação projeto Original e Novo

Danos: Projeto Original

1982 até 1993 – material SA-312 TP316

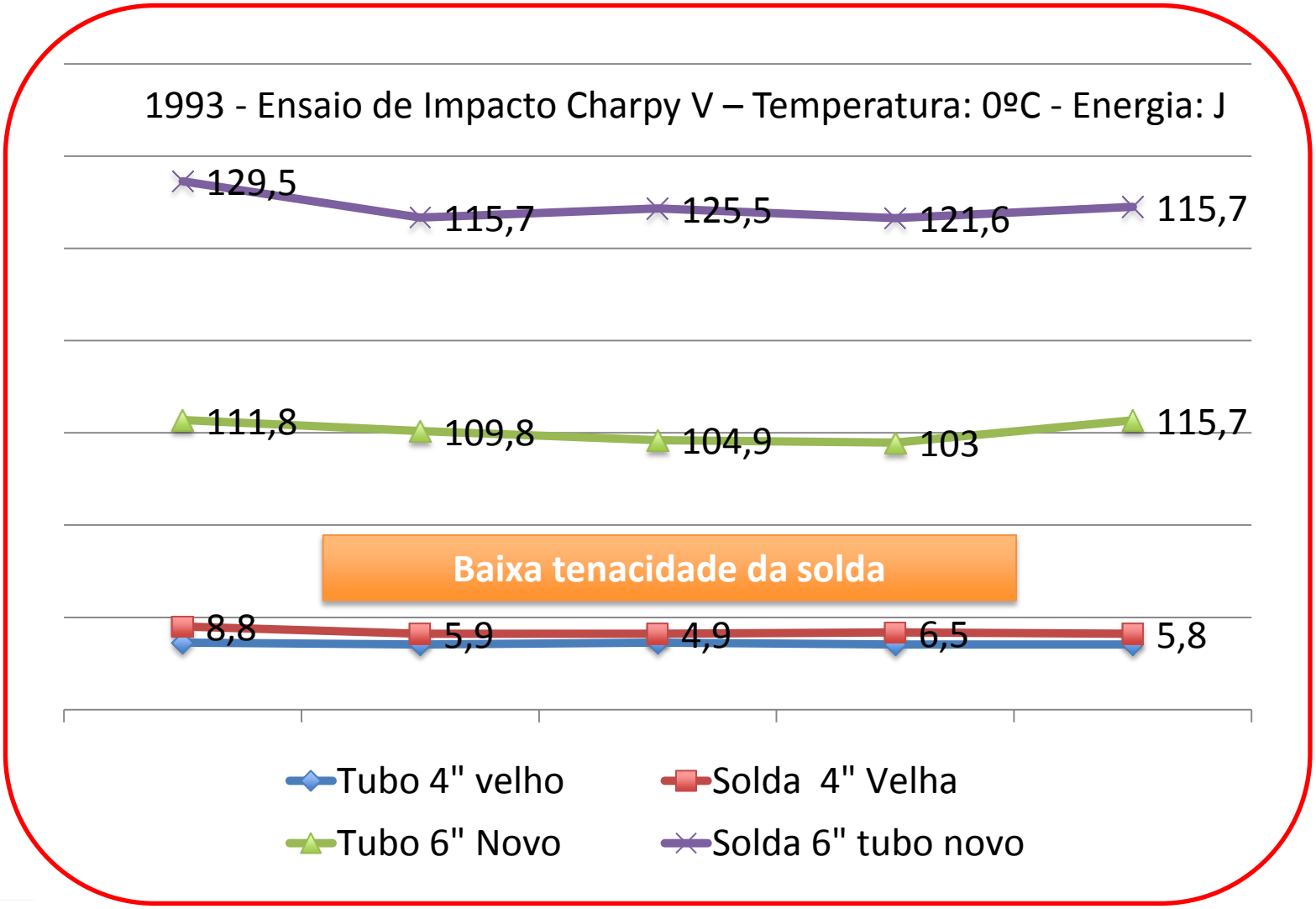
Tempo operação: 97.000 h

Danos: trincas em solda

Causa: formação de fase sigma oriunda de ferrita delta da solda original, pela exposição em temperatura de 650ºC

Ensaios de Impacto nas soldas indicou baixa tenacidade
Dureza elevada

Recomendação Projetista: Substituição por INCOLOY 800HT


1993 - Ensaio de Impacto Charpy V – Temperatura: 0ºC - Energia: J
129,5
115,7
125,5
121,6
115,7
111,8
109,8
104,9
103
115,7
Baixa tenacidade da solda
8,8
5,9
4,9
6,5
5,8
Tubo 4" velho
Solda 4" Velha
Tubo 6" Novo
Solda 6" tubo novo

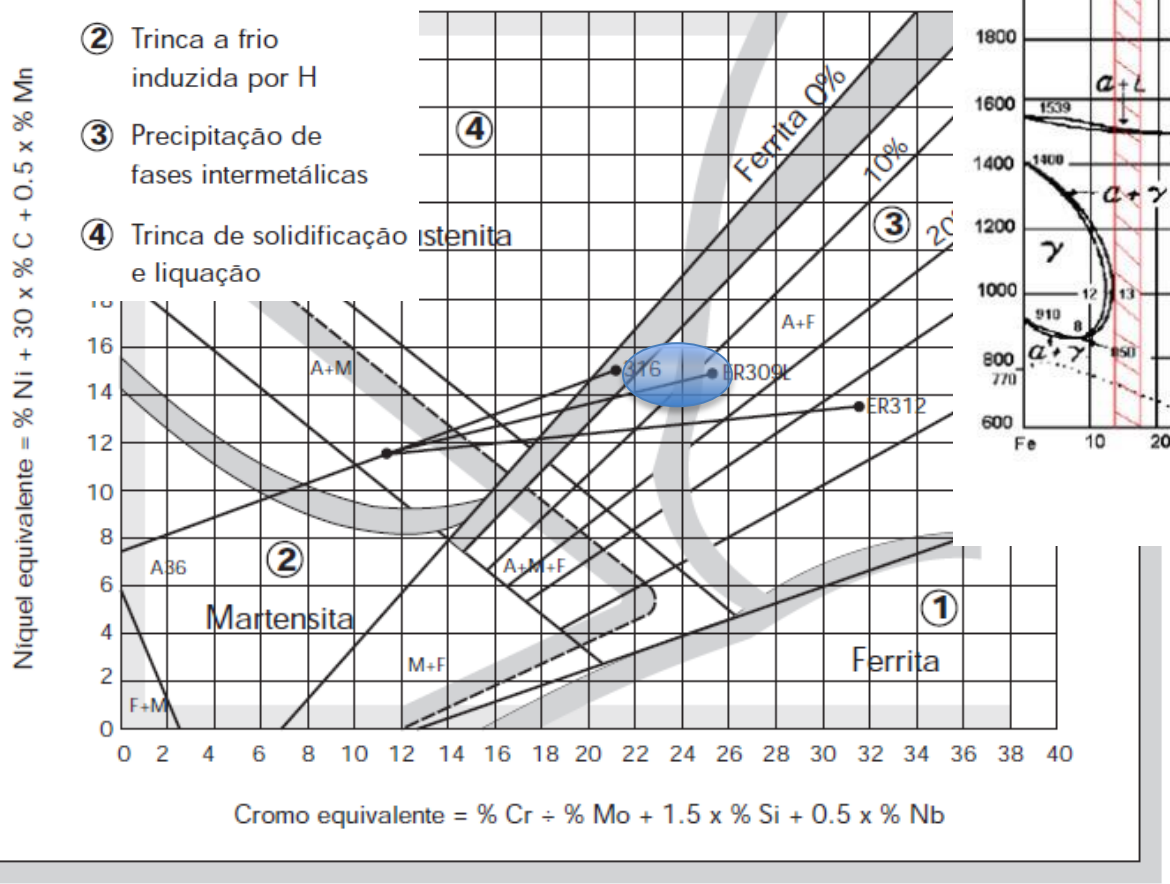
Fase Sigma

① Crescimento de grão

② Trinca a frio induzida por H

③ Precipitação de fases intermetálicas

④ Trinca de solidificação e liquação



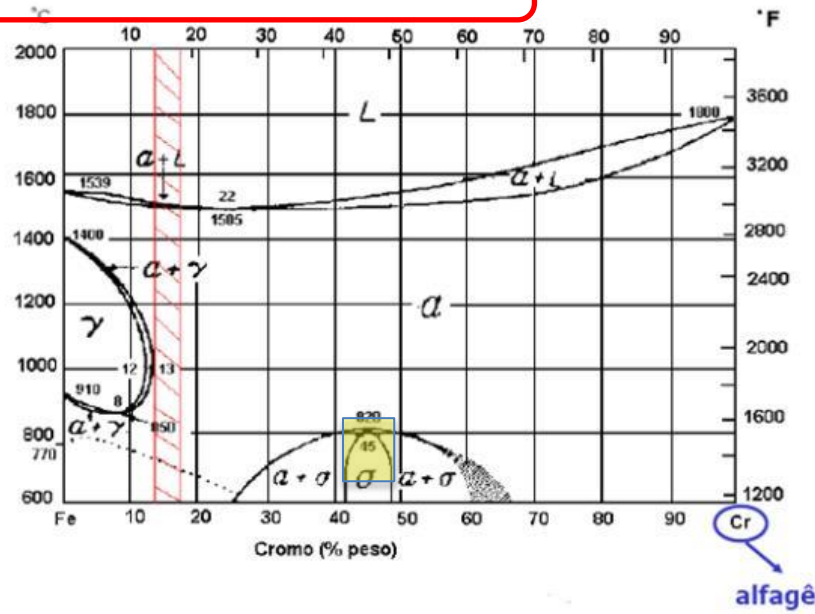


Diagrama de Schaeffler

1993 - Projeto Revisado

Material: ASTM SB 407 UNS 08811 [*INCOLOY 800HT*]

Solda: AWS 5.14 ERNiCrCoMo-1 UNS N06617 [*INCONEL 617*]

Sem TTAT

1993 - Projeto Revisado

Material: ASTM SB 407 UNS 08811 [*INCOLOY 800HT*]

Tubo extrudado da Liga de Fe-Cr-Ni com Carbono controlado e endurecida por solução sólida com Recozimento acima de 1148ºC

Alta resistência a Carburização e Oxidação em Altas Temperaturas (acima de 590ºC) com alta Resistência Mecânica e a Fluência.

Não forma fase sigma em longa exposição a 650ºC, não se tornando frágil.
Facilidade de soldagem

Os Materiais: INCOLOY 800HT

Table 1 - Limiting Chemical Compositions, %, for INCOLOY alloys 800, 800H, and 800HT

General Requirements			
UNS designation	**N08800**	**N08810**	**N08811**
INCOLOY alloys	**800**	**800H**	**800HT**
Nickel	30.0-35.0	30.0-35.0	30.0-35.0
Chromium	19.0-23.0	19.0-23.0	19.0-23.0
Iron	39.5 min.	39.5 min.	39.5 min.
Carbon	0.10 max.	0.05-0.10	0.06-0.10
Aluminum	0.15-0.60	0.15-0.60	0.25-0.60
Titanium	0.15-0.60	0.15-0.60	0.25-0.60
Aluminum + Titanium	0.30-1.20	0.30-1.20	0.85-1.20
ASTM grain size	Not specified	5 or coarser	5 or coarser

Special Grain Size Requirements* INCOLOY alloys 800H and 800HT	
Plate	ASTM 1-5
Tube/Pipe	ASTM 1-5
Sheet	ASTM 2-5

*As agreed for specific orders.

MECHANICAL PROPERTIES (B) OF PIPE AND TUBE

Alloy	Condition (Temper)	Tensile Strength, min, psi (MPa)	Yield Strength, (0.2% offset), min, psi (MPa)	Elongation in 2 in. or 50 mm (or 4*D*), min, %
UNS N08120	hot-finished annealed or cold-worked annealed	90 000 (621)	40 000 (276)	30
UNS N08800	cold-worked annealed	75 000 (520)	30 000 (205)	30
UNS N08800	hot-finished annealed or hot-finished	65 000 (450)	25 000 (170)	30
UNS N08810 and UNS N08811	hot-finished annealed or cold-worked annealed	65 000 (450)	25 000 (170)	30
UNS N08801	hot-finished annealed or cold-worked annealed	65 000 (450)	25 000 (170)	30
UNS N08890	hot-finished annealed or cold-worked annealed	75 000 (520)	30 000 (205)	35
UNS N06811	hot-finished annealed or cold-worked annealed	85 000 (585)	35 000 (240)	30

INCOLOY® alloy 800H & 800HT®

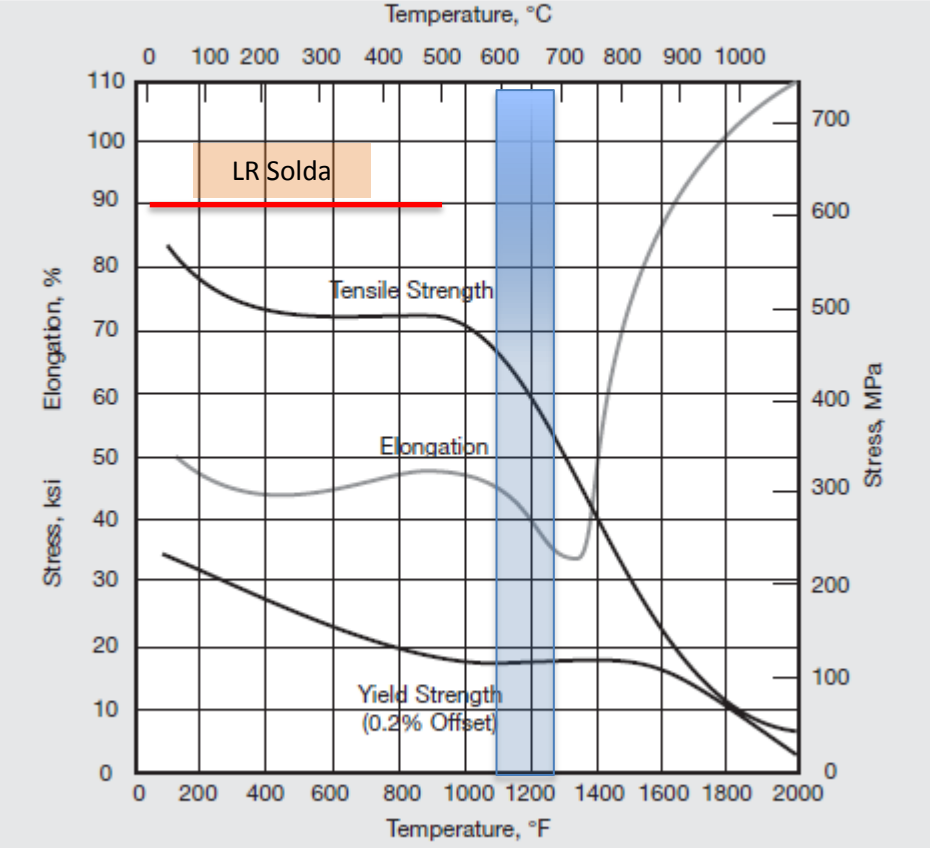


Figure 1. High-temperature strength tensile properties of INCOLOY alloys 800H and 800HT.

Consumível de Soldagem

SPECIFICATION FOR NICKEL AND NICKEL-ALLOY WELDING ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.11/SFA-5.11M

SPECIFICATION FOR NICKEL AND NICKEL-ALLOY BARE WELDING ELECTRODES AND RODS

SFA-5.14/SFA-5.14M

Table 1 (Continued)
Chemical Composition Requirements for Nickel and Nickel-Alloy Electrodes and Rods

		Weight Percent[a, b]																
AWS Classification[m]	UNS Number[c]	C	Mn	Fe	P	S	Si	Cu	Ni[d]	Co	Al	Ti	Cr	Nb(Cb) Plus Ta	Mo	V	W	Other Elements, Total
ERNiCrCoMo-1	N06617	0.05 to 0.15	1.0	3.0	0.03	0.015	1.0	0.50	Rem	10.0 to 15.0	0.8 to 1.5	0.60	20.0 to 24.0	—	8.0 to 10.0	—	—	0.50

ALL-WELD-METAL TENSION TEST REQUIREMENTS (CONT'D)

AWS Classification	Tensile Strength, min. ksi	Tensile Strength, min. MPa	Elongation[a] Percent, min.
	NiCrCoMo		
ENiCrCoMo-1	90	620	20
	NiCrWMo		
ENiCrWMo-1	90	620	20

Consumível de Soldagem – API 582

Base Material (See Note 1)	70-30 and 90-10 Cu-Ni	Alloy 400 (N04400)	Nickel 200 (N02200)	Alloy 800 (N08800), 800H (N08810), 800HT (N08811)
carbon and low-alloy steel	BC	BC	C	A
300 series stainless steel	BC	AC	AC	A
400 series stainless steel	B	B	AC	A
70-30 and 90-10 Cu-Ni	B	B	C	C
Alloy 400 (N04400)		B	BC	A
Nickel 200 (N02200)			C	AC
Alloy 800 (N08800), 800H (N08810), 800HT (N08811) (see Note 2)				K

K ASME/AWS SFA/A 5.11, Classification ENiCrCoMo-1 or matching filler.

NOTE 2 For Alloys 800, 800H, and 800HT, if sulfidation or stress relaxation cracking is a concern, use matching filler metals.

Consumível de Soldagem – PETROBRAS N-133

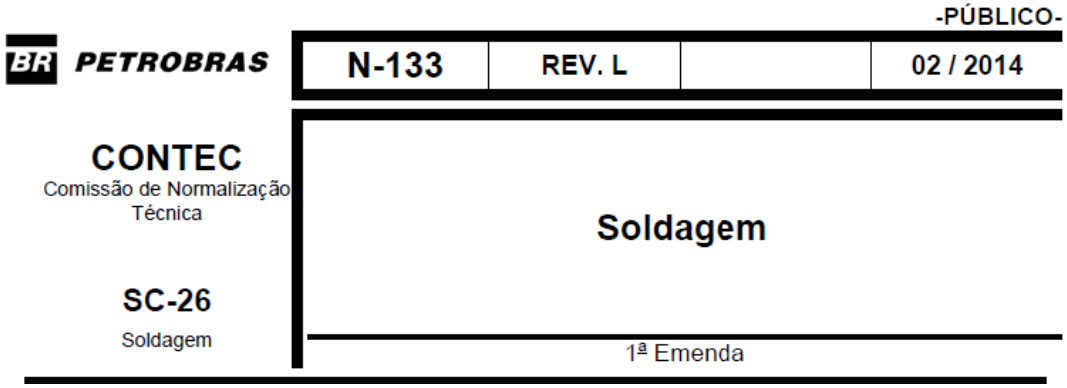


Tabela 20 - Eletrodos, Varetas e Arames Sólidos para Níquel e Ligas de Níquel

Alloy 800/800H/ 800HT	A5.11	ENiCrCoMo-1		A5.14	ERNiCrCoMo-1

1993 - Projeto Revisado

Material: ASTM SB 407 UNS 08811 [*INCOLOY 800HT*]

Histórico da Liga

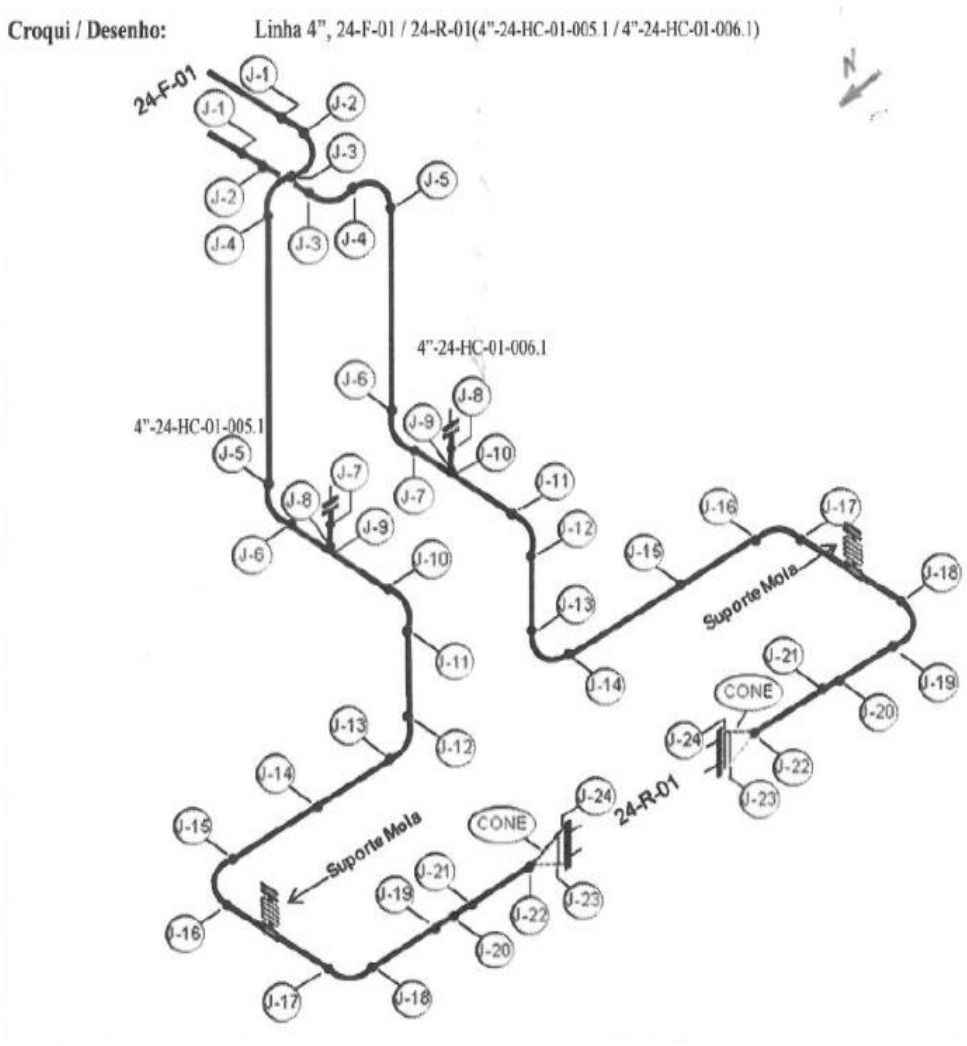
Ano	Evento	Aplicação
1950 a 1990	descoberta e uso das ligas INCOLOY	Resistência corrosão e resistência em alta temperatura
1963	aprovado pelo ASME VIII	Uso em tubos e componentes de fornos, pig-tail, coletores
1987	INCOLOY 800HT foi aceita pelo ASME VIII	É variação do 800H para garantir as tensões admissíveis em altas temperaturas. Composição química equivalente 800H com tratamento de recozimento (1149ºC): produz grãos médio acima de ASTM 5. Faixas de C e Al+Ti controladas. Alta resistência a fluência e mecânica em altas temperaturas.

1993 - Projeto Revisado

Materiais Adquiridos

Requisito	Material Recebido	Especificação
Tratamento Térmico	Recozimento a 1200ºC por 5 minutos, resfriado em água	1149ºC min
Limite de Resistência [MPa]	530	450
Tensão de Escoamento [MPa]	241	170
Alongamento - %	54	30
Tamanho do Grão	ASTM E 112 nº 2 e 3	Máximo nº5
Dureza	60 – 66 HRB	

Identificação das Soldas



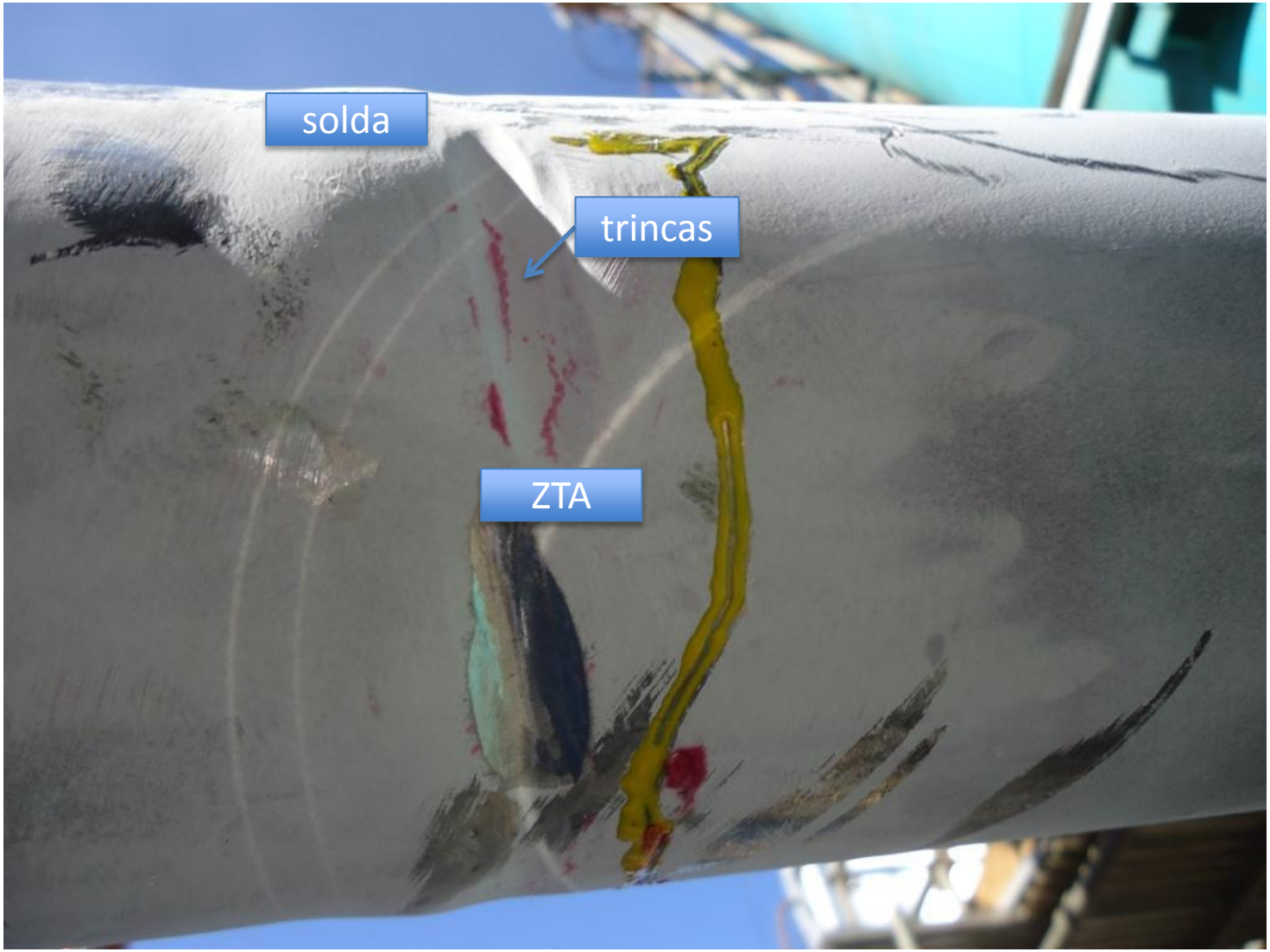
Inspeção – Mecanismo de Danos

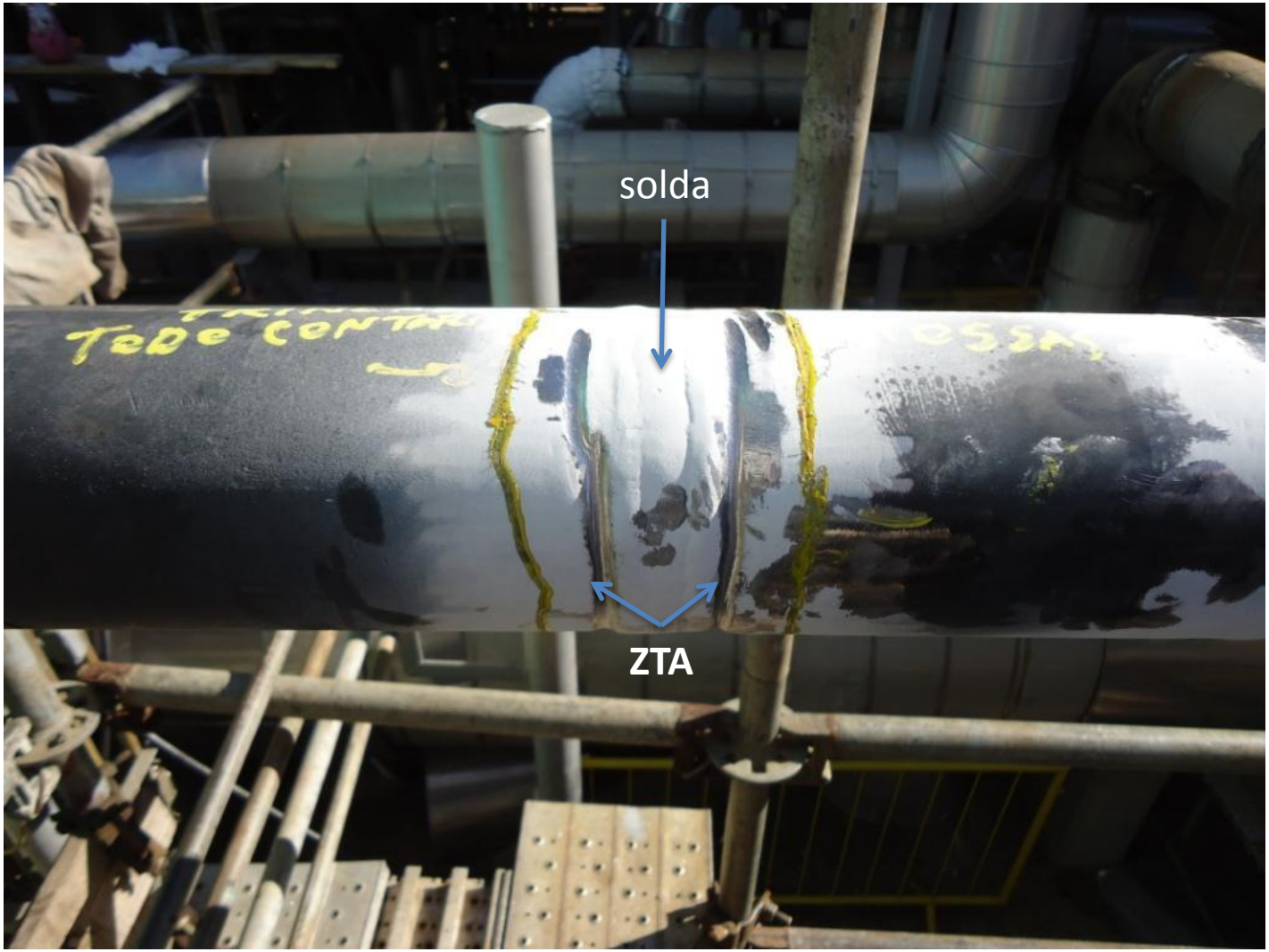
Parada de 2014

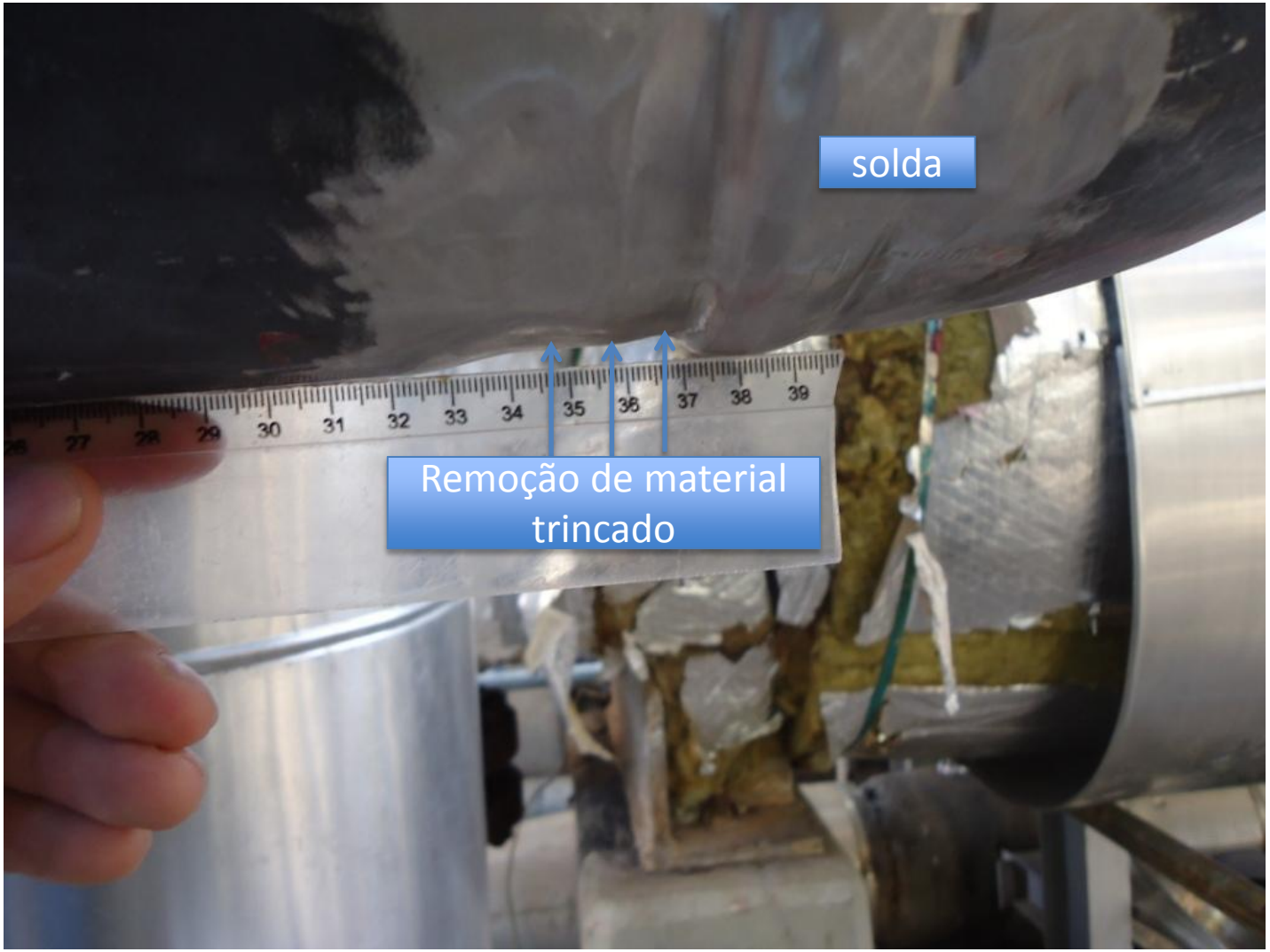
Material: ASTM SB 407 UNS 08811 [*INCOLOY 800HT*]

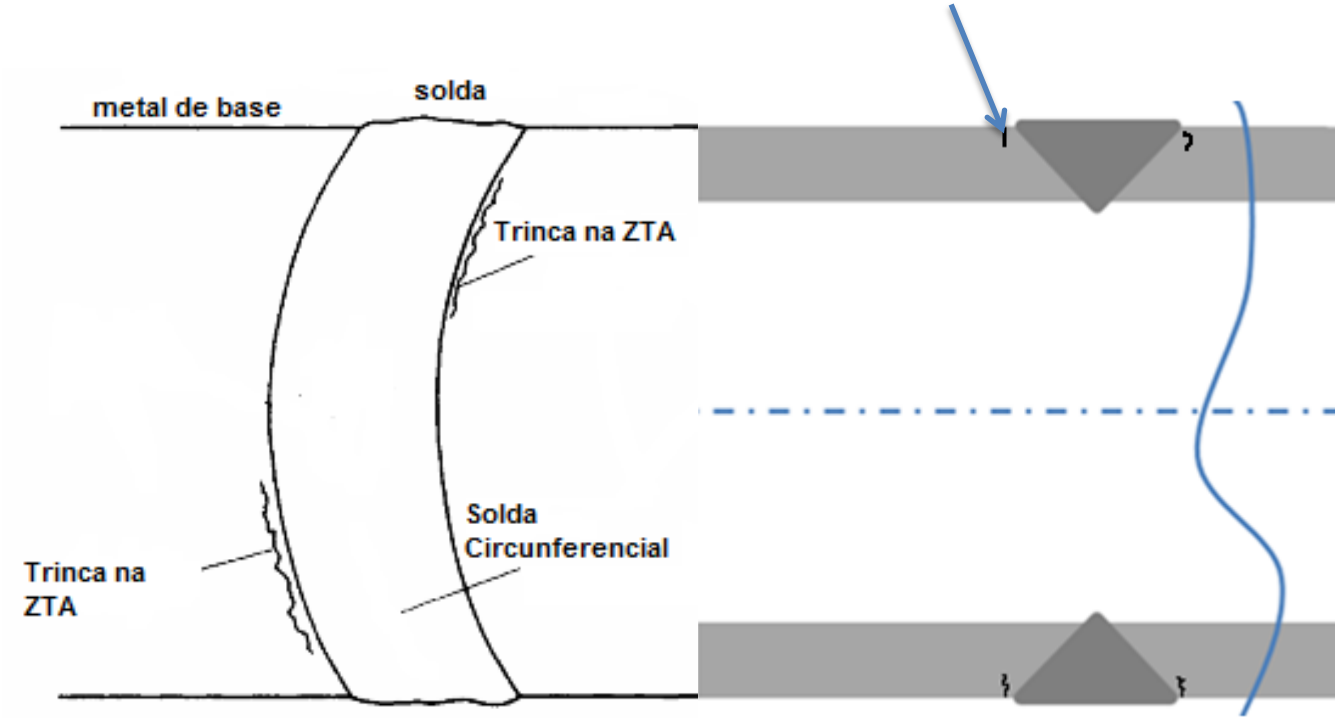
Tempo de Operação: 110.000 h [aprox. 70% de 18 anos]

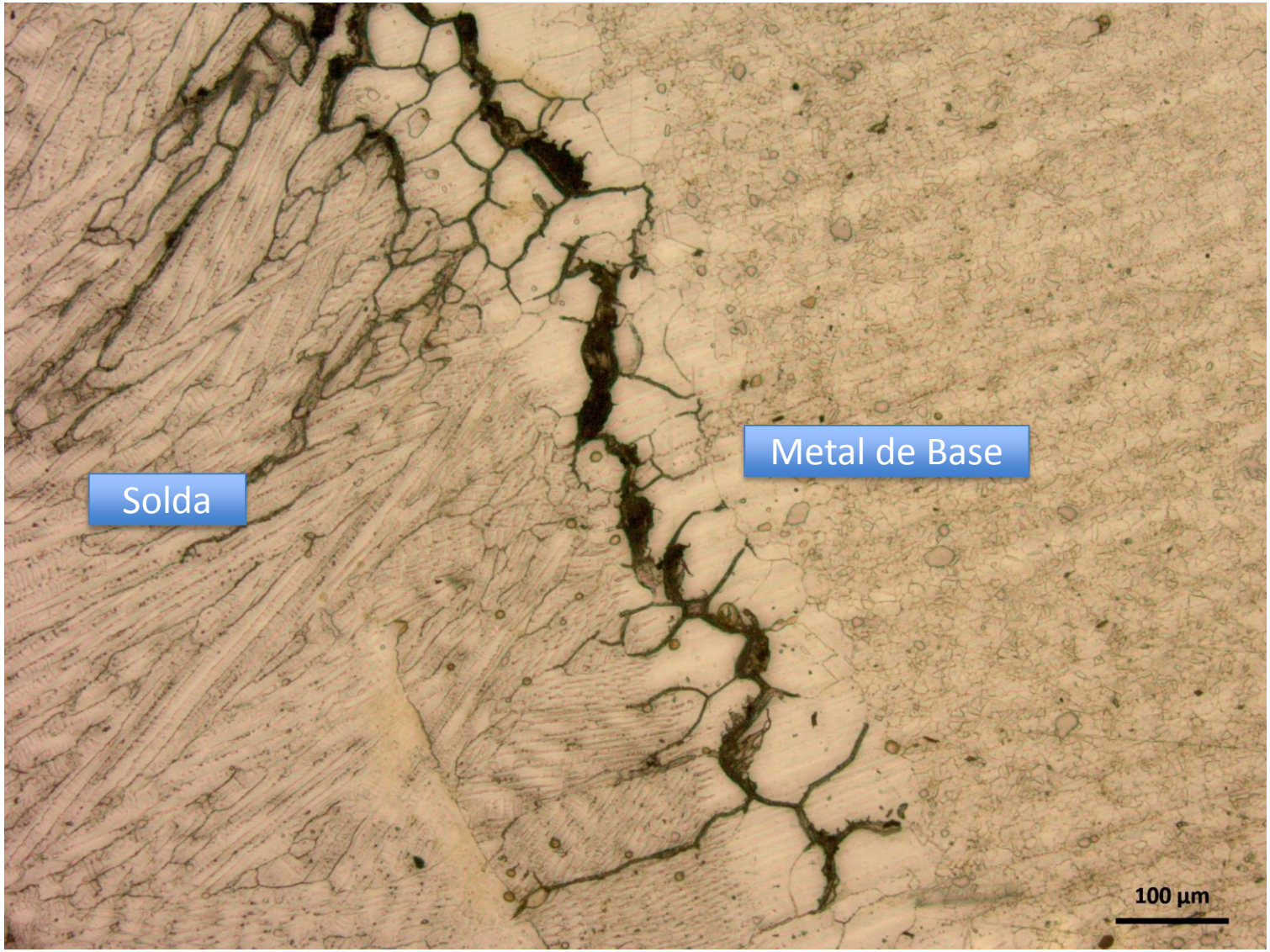
Ensaio: Solda e ZTA	Resultado	Laudo
Corrente Parasita	Baixa efetividade	Necessária remoção de óxido espesso
Líquido Penetrante	Trincas em 70% das ZTA das soldas	Trincas circunferenciais paralelas as soldas
Réplica Metalográfica	Trincas nas ZTA, contornos de grão	Trincas de Relaxação

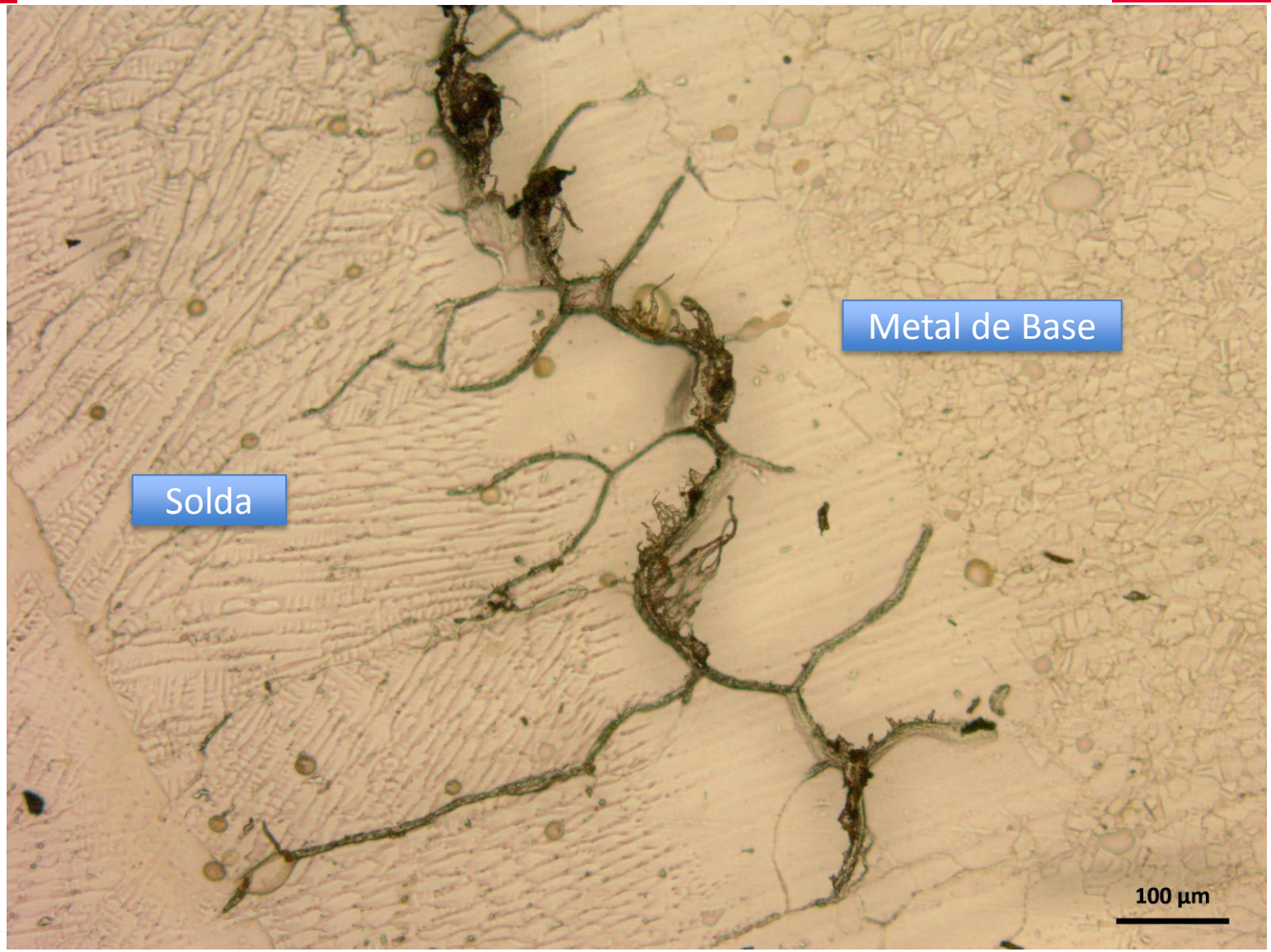

solda
trincas
ZTA

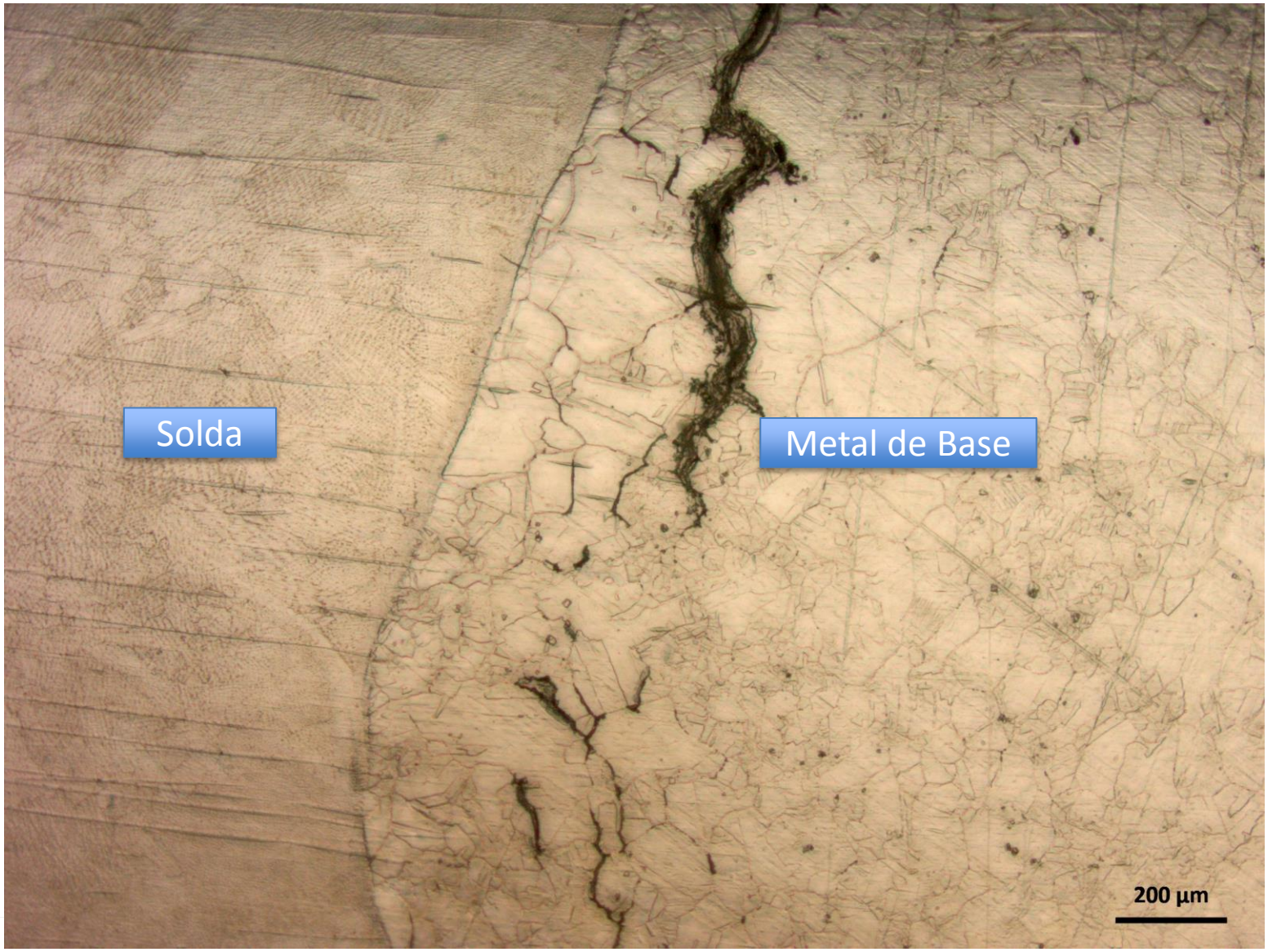

solda
ZTA


solda
Remoção de material trincado


metal de base
solda
Trinca na ZTA
Solda
Circunferencial
Trinca na
ZTA


Solda
Metal de Base
100 µm


Metal de Base
Solda
100 µm


Solda
Metal de Base
200 µm

Causa do Dano

A liga INCOLOY 800HT (UNS N08811) é indicada pela literatura como suscetível a trincas de reaquecimento (*reheat cracking*), também chamada como trinca de relaxação ou relaxamento (*relaxation cracking or stress relief cracking*).

energy API

Damage Mechanisms Affecting Fixed Equipment in the Refining Industry

RECOMMENDED PRACTICE 571

Materials, Fabrication, and Repair Considerations for Hydrogen Reformer Furnace Outlet Pigtails and Manifolds

API PUBLICATION XXXX
REVISED DRAFT 03, APRIL 2011

DRAFT

Mecanismo do Dano

As **altas resistências** mecânicas em altas temperaturas dos materiais de **solda** utilizados acabam produzindo efeitos negativos no metal de base, causando o relaxamento das tensões de soldagem em operação, pela deformação nos contornos de grão da ZTA.

Cuidados devem ser recomendados para reduzir o risco de trincamento durante a fabricação e operação.

Mecanismo de dano *recente* na indústria!

API 571: causas

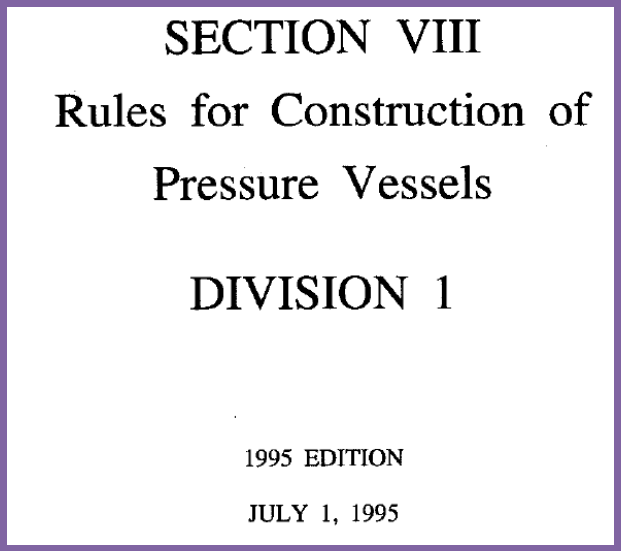
1. Necessário altas tensões: sendo mais provável em espessuras altas de materiais de alta resistência mecânica;
2. Em elevadas temperaturas onde a dutilidade a fluência não acomodaria as tensões residuais;
3. Precipitação nos contornos fazendo com que o grão seja mais resistente e induzindo a deformação intergranulares;
4. Morfologia: Tipicamente nas regiões de grãos grosseiros da ZTA da solda, podendo ser externas ou internas (embebidas);
5. Localização: Iniciam em algum concentrador de tensões e podem ter relação com fadiga;

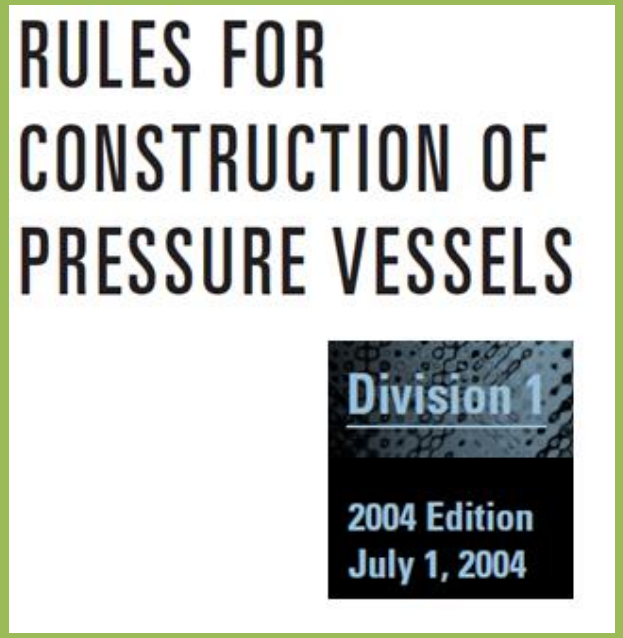
API 571 – Mitigação

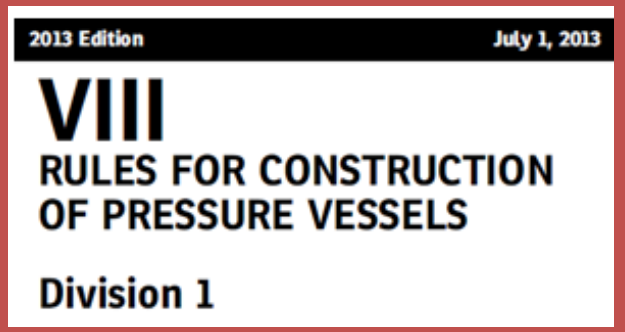
1. Configuração da solda evitando juntas com restrição.
2. Entalhes metalúrgicos originados da soldagem influem no trincamento da ZTA;
3. Solda: projeto e fabricação devem evitar alterações bruscas nas seções soldadas: raio da solda de filete e mordeduras são fortes concentradores de tensão;
4. Soldagem com TTAT adequado.

PART UNF
REQUIREMENTS FOR PRESSURE VESSELS CONSTRUCTED OF NONFERROUS MATERIALS

UNF-56 POSTWELD HEAT TREATMENT







1995 2004 2013

UNF-56	1995	2004	2013
(a)	Mesmo requisito		
(b)	Mesmo requisito*		
(c)	Mesmo requisito		
(d)	Mesmo requisito		

(a) Postweld heat treatment of nonferrous materials is not normally necessary nor desirable.

(b) Except as in (c) and (d) below, no postweld heat treatment shall be performed except by agreement between the user and the manufacturer. The temperature, time and method of heat treatment shall be covered by agreement.

(c) If welded, castings of SB-148, Alloy CDA 954 shall be heat treated after all welding at 1150°F–1200°F for 1½ hr at temperature for the first inch of cross section thickness plus ½ hr for each additional inch of section thickness. Material shall then be air cooled.

(d) Within 14 days after welding, all products of zirconium Grade R60705 shall be heat treated at 1000°F–1100°F for a minimum of 1 hr for thicknesses up to 1 in. plus ½ hr for each additional inch of thickness. Above 800°F, cooling shall be done in a closed furnace or cooling chamber at a rate not greater than 500°F/hr divided by the maximum metal thickness of the shell or head plate in inches but in no case more than 500°F/hr. From 800°F, the vessel may be cooled in still air.

1995

(a) Postweld heat treatment of nonferrous materials is not normally necessary nor desirable.

(b) Except as in (c), (d), and (e) below, no postweld heat treatment shall be performed except by agreement between the user and the Manufacturer. The temperature, time and method of heat treatment shall be covered by agreement.

(c) If welded, castings of SB-148, Alloy CDA 954 shall be heat treated after all welding at 1150°F–1200°F (620°C–650°C) for 1½ hr at temperature for the first inch of cross section thickness plus ½ hr for each additional inch of section thickness. Material shall then be air cooled.

(d) Within 14 days after welding, all products of zirconium Grade R60705 shall be heat treated at 1,000°F–1,100°F (540°C–595°C) for a minimum of 1 hr for thicknesses up to 1 in. (25 mm) plus ½ hr for each additional inch of thickness. Above 800°F (425°C), cooling shall be done in a closed furnace or cooling chamber at a rate not greater than 500°F/hr (278°C/hr) divided by the maximum metal thickness of the shell or head plate in inches but in no case more than 500°F/hr (278°C/hr). From 800°F (425°C), the vessel may be cooled in still air.

2004

(a) Postweld heat treatment of nonferrous materials is not normally necessary nor desirable.

(b) Except as in (c), (d), and (e) below, no postweld heat treatment shall be performed except by agreement between the user and the Manufacturer. The temperature, time and method of heat treatment shall be covered by agreement.

(c) If welded, castings of SB-148, Alloy CDA 954 shall be heat treated after all welding at 1,150°F to 1,200°F (620°C to 650°C) for 1½ hr at temperature for the first inch of cross section thickness plus ½ hr for each additional inch of section thickness. Material shall then be air cooled.

(d) Within 14 days after welding, all products of zirconium Grade R60705 shall be heat treated at 1,000°F to 1,100°F (540°C to 595°C) for a minimum of 1 hr for thicknesses up to 1 in. (25 mm) plus ½ hr for each additional inch of thickness. Above 800°F (425°C), cooling shall be done in a closed furnace or cooling chamber at a rate not greater than 500°F/hr (278°C/h) divided by the maximum metal thickness of the shell or head plate in inches but in no case more than 500°F/hr (278°C/h). From 800°F (425°C), the vessel may be cooled in still air.

2013

UNF-56	1995	2004	2013
(e)	*Inexistente*	*Mesmo requisito*	

(e) Postweld Heat Treatment of UNS Nos. N08800, N08810, and N08811 Alloys

(1) Pressure boundary welds and welds to pressure boundaries in vessels with design temperatures above 1000°F fabricated from UNS No. N08800 (Alloy 800), UNS No. N08810 (Alloy 800H), and UNS No. N08811 (Alloy 800HT) shall be postweld heat treated. The postweld heat treatment shall consist of heating to a minimum temperature of 1,625°F (885°C) for 1½ hr for thicknesses up to 1 in. (25 mm), and for 1½ hr + 1 hr/in. of thickness for thicknesses in excess of 1 in. (25 mm). Cooling and heating rates shall be by agreement between the purchaser and fabricator. As an alternative, solution annealing in accordance with the material specification is acceptable. Postweld heat treatment of tube-to-tubesheet and expansion bellows attachment welds is neither required nor prohibited.

(2) Except as permitted in (3) below, vessels or parts of vessels that have been postweld heat treated in accordance with the requirements of this paragraph shall again be postweld heat treated after welded repairs have been made.

(e) Postweld Heat Treatment of UNS Nos. N08800, N08810, and N08811 Alloys

(1) Pressure boundary welds and welds to pressure boundaries in vessels with design temperatures above 1000°F fabricated from UNS No. N08800 (Alloy 800), UNS No. N08810 (Alloy 800H), and UNS No. N08811 (Alloy 800HT) shall be postweld heat treated. The postweld heat treatment shall consist of heating to a minimum temperature of 1,625°F (885°C) for 1½ hr for thicknesses up to 1 in. (25 mm), and for 1½ hr + 1 hr/in. of thickness for thicknesses in excess of 1 in. (25 mm). Cooling and heating rates shall be by agreement between the user or his designated agent and the Manufacturer. As an alternative, solution annealing in accordance with the material specification is acceptable. Postweld heat treatment of tube-to-tubesheet and expansion bellows attachment welds is neither required nor prohibited.

(2) Except as permitted in (3) below, vessels or parts of vessels that have been postweld heat treated in accordance with the requirements of this paragraph shall again be postweld heat treated after welded repairs have been made.

1995 2004 2013

UNF-56	1995	2004	2013
(e)	*Inexistente*	*Mesmo requisito*	

(3) Weld repairs to the weld metal and heat affected zone in welds joining these materials may be made after the final PWHT, but prior to the final hydrostatic test, without additional PWHT. The weld repairs shall meet the requirements of (e)(3)(a) through (e)(3)(d) below.

(a) The Manufacturer shall give prior notification of the repair to the user or to his designated agent and shall not proceed until acceptance has been obtained.

(b) The total repair depth shall not exceed ½ in. (13 mm) or 30% of the material thickness, whichever is less. The total depth of a weld repair shall be taken as the sum of the depths for repairs made from both sides of a weld at a given location.

(c) After removal of the defect, the groove shall be examined. The weld repair area must also be examined. The liquid penetrant examination method, in accordance with Appendix 8, shall be used.

(d) The vessel shall be hydrostatically tested after making the welded repair.

(f) Postweld heat treatment of UNS R31233 is required prior to cold forming when the cold forming bend radius at the weld is less than four(4) times the thickness of the component. Postweld treatment shall consist of annealing at 2,050°F (1 121°C) immediately followed by water quenching.

(3) Weld repairs to the weld metal and heat affected zone in welds joining these materials may be made after the final PWHT, but prior to the final hydrostatic test, without additional PWHT. The weld repairs shall meet the requirements of (-a) through (-d) below.

(-a) The Manufacturer shall give prior notification of the repair to the user or to his designated agent and shall not proceed until acceptance has been obtained.

(-b) The total repair depth shall not exceed ½ in. (13 mm) or 30% of the material thickness, whichever is less. The total depth of a weld repair shall be taken as the sum of the depths for repairs made from both sides of a weld at a given location.

(-c) After removal of the defect, the groove shall be examined. The weld repair area must also be examined. The liquid penetrant examination method, in accordance with Mandatory Appendix 8, shall be used.

(-d) The vessel shall be hydrostatically tested after making the welded repair.

(f) Postweld heat treatment of UNS R31233 is required prior to cold forming when the cold forming bend radius at the weld is less than 4 times the thickness of the component. Postweld treatment shall consist of annealing at 2,050°F (1 121°C) immediately followed by water quenching.

1995 2004 2013

Segundo ASME VIII Div1, UNF-56 ligas INCOLOY 800HT devem ser tratadas termicamente para alívio de tensões a 885°C.

Tratamento térmico não foi realizado em 1993 nestas juntas.

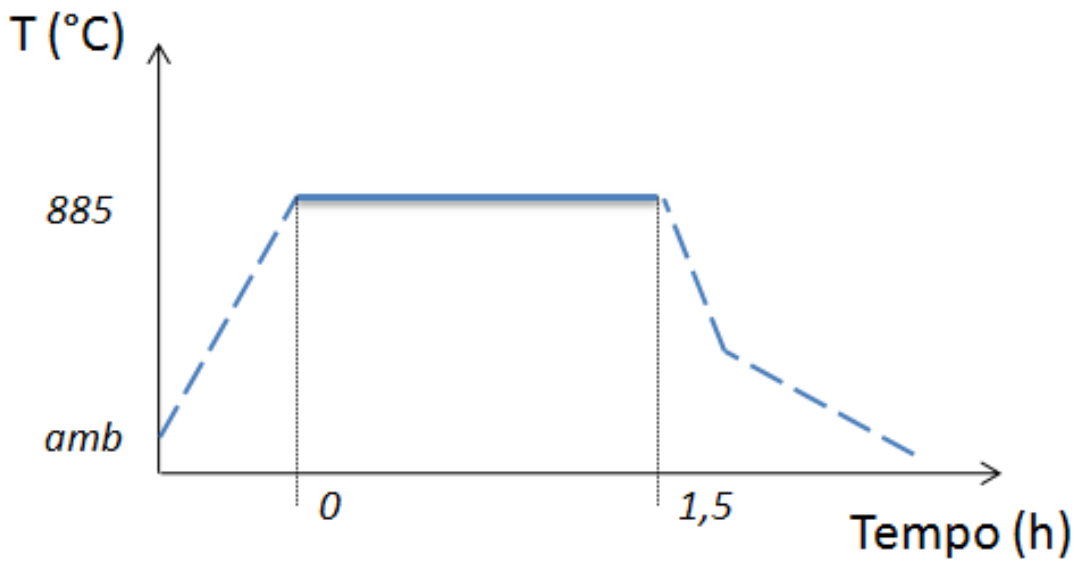
Welding Guidelines for the Chemical, Oil, and Gas Industries 2009

Table 5—PWHT Temperature and Holding Time (Continued)

P-no.	Material Type	Nominal Thickness at Weld (in.)	Service Environment	Holding Temperature (°F) [a]	Time at Holding Temperature (hr)
10H	duplex stainless steels	according to code	all	according to code	1 hr/in. (1 minimum)
11A	8 Ni, 9 Ni	according to code	all	according to code	1 hr/in. (1 minimum)
45	alloy, 800, 800H, 800HT	according to code	all	according to code	according to code

Tratamento térmico de alívio de tensões

- O tratamento térmico proposto segue ASME VIII Div 1 UNF-56

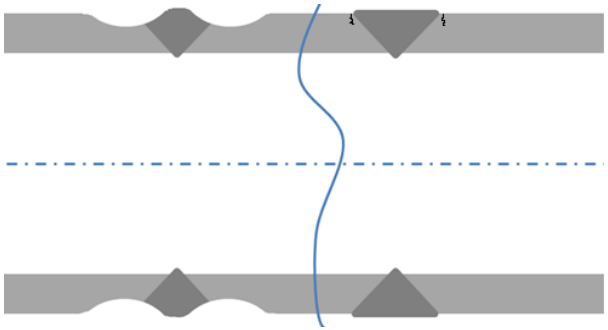


Reparos

Solução do Problema

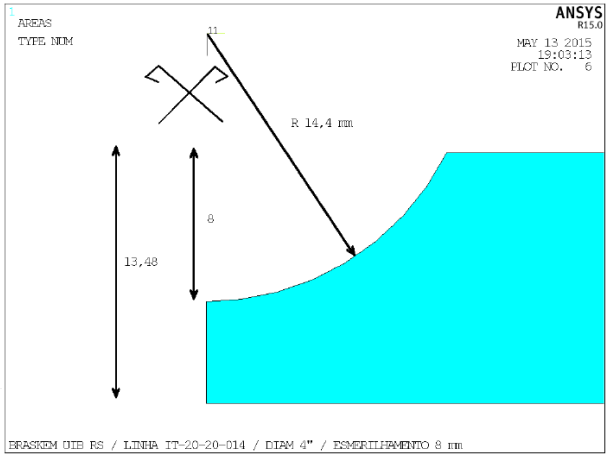
- Determinar o tamanho crítico de remoção de material com adoçamento;
- Não fazer solda de enchimento, somente soldas de topo;
- Emitir Procedimento para solda de topo;
- Reduzir o número de juntas soldadas com defeito;
- Definir tratamento térmico de alívio de tensões;

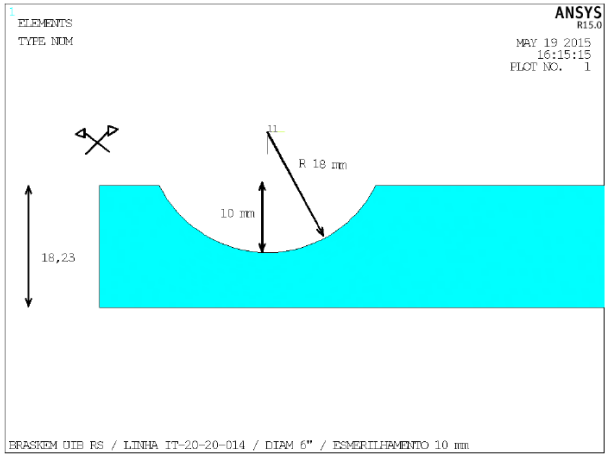
Determinar o tamanho crítico de remoção de material com adoçamento



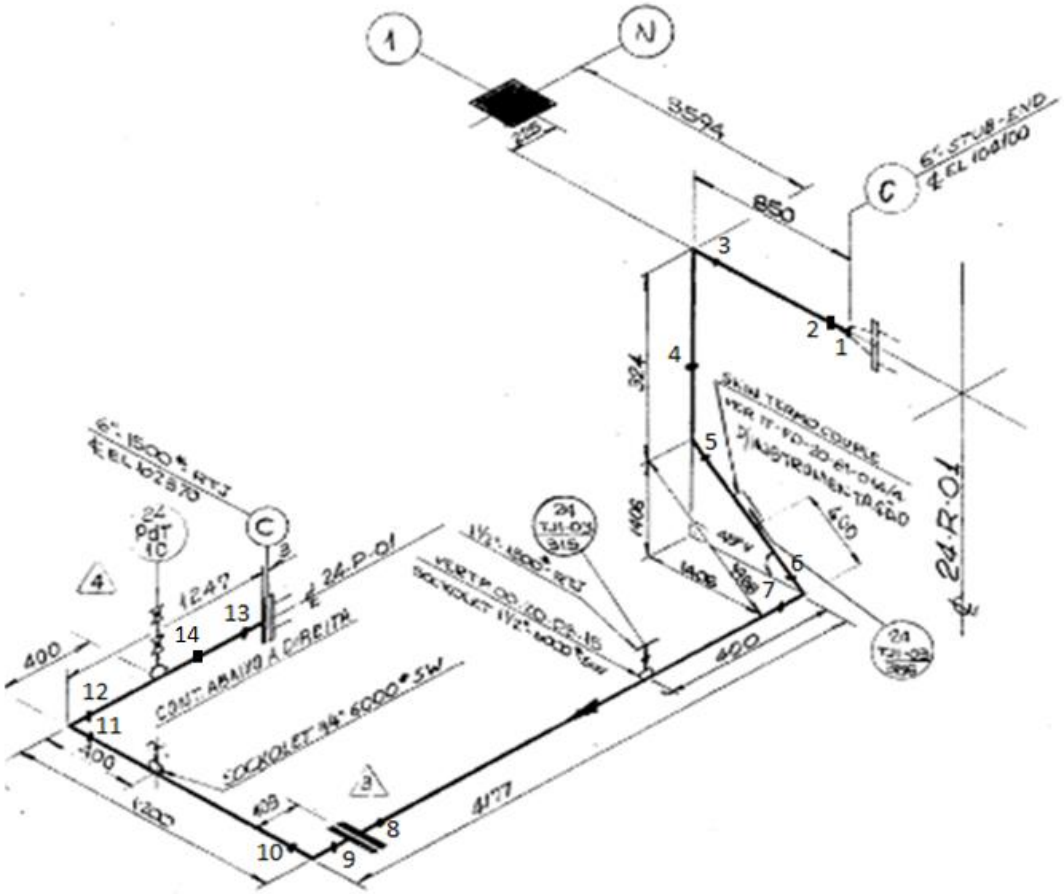
Tubulações de 4” -> são permitidas descontinuidades de **4mm de profundidade**.

Tubulações de 6” - > são permitidas descontinuidades de **5mm de profundidade.**



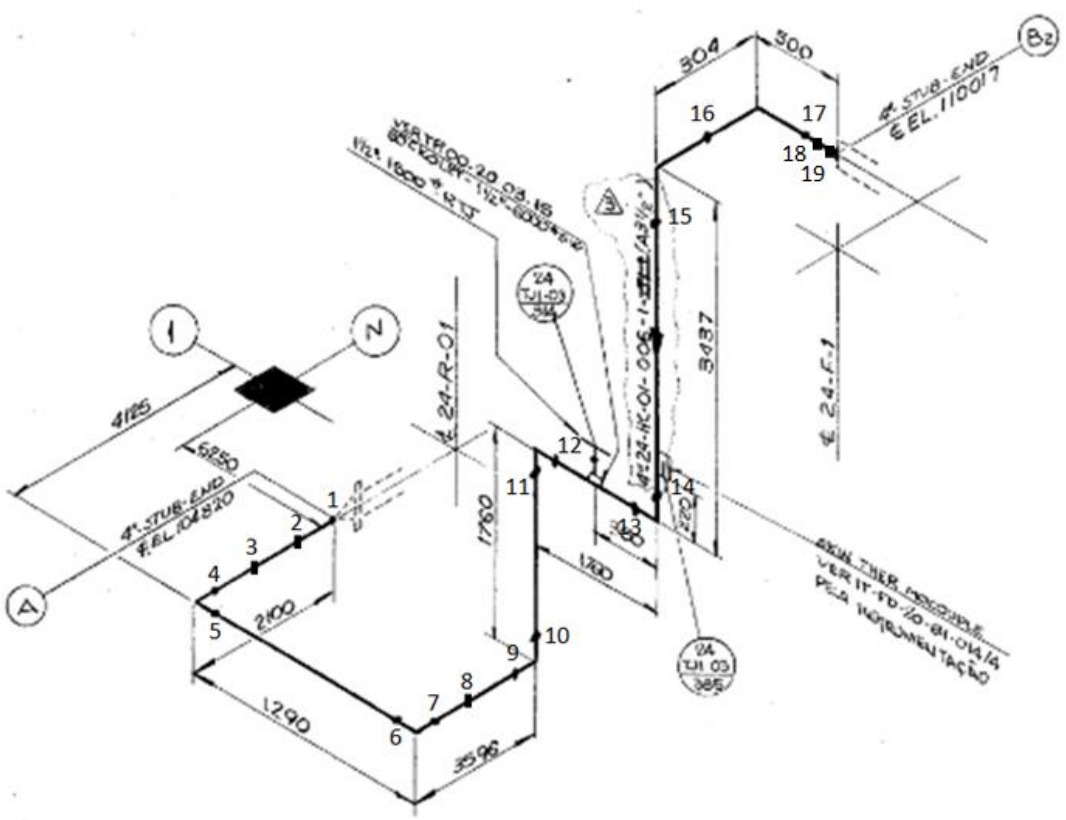


Descontinuidades encontradas – 6”



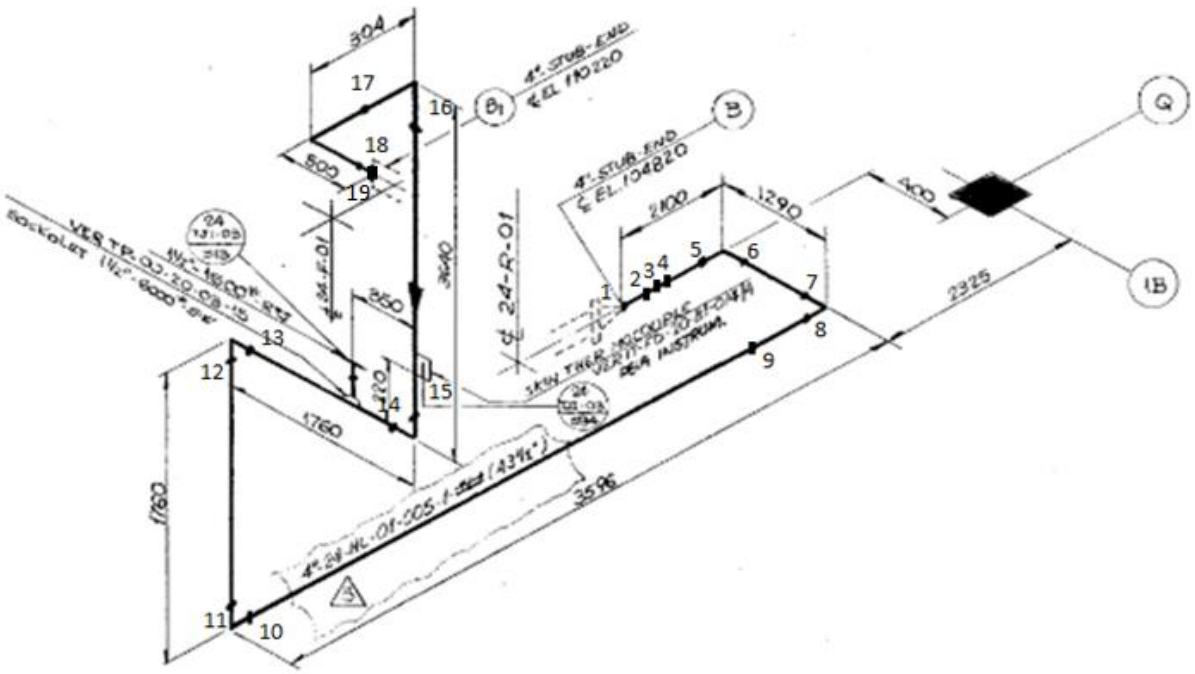
Solda	*Toda indicação foi removida no campo?*	*Profundidade da remoção (mm)*
1	NÃO	12
2	NÃO	15
3	SIM	6
4	SIM	-
5	SIM	3
6	SIM	7
7	SIM	7
8	SIM	-
9	SIM	-
10	SIM	2
11	SIM	2
12	SIM	6
13	SIM	5
14	SIM	6

Descontinuidades encontradas – 4”-Sul

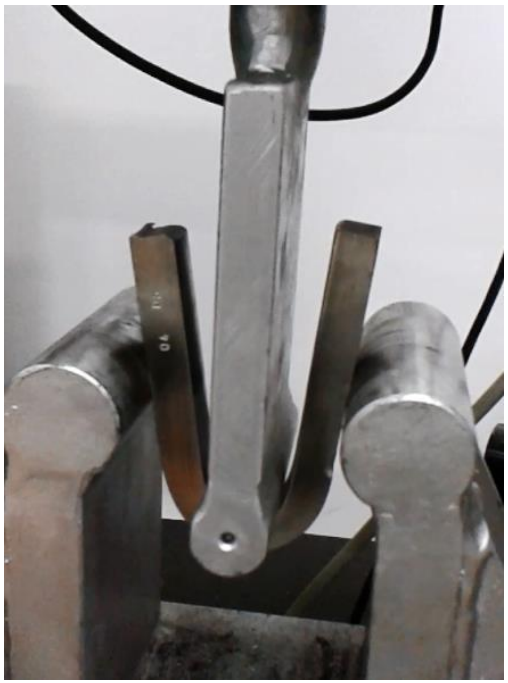


Solda	*Toda indicação foi removida no campo?*	*Profundidade da remoção (mm)*
1	SIM	-
2	SIM	5
3	NÃO	9
4	SIM	-
5	SIM	-
6	SIM	1
7	SIM	2
8	SIM	5
9	SIM	3
10	SIM	3
11	SIM	1
12	SIM	2
13	NÃO	7
14	SIM	1
15	SIM	-
16	SIM	-
17	SIM	-
18	SIM	3
19	SIM	2

Descontinuidades encontradas – 4”-Norte



Solda	*Toda indicação foi removida no campo?*	*Profundidade da remoção (mm)*
1	SIM	2
2	NÃO	9
3	NÃO	9
4	NÃO	9
5	SIM	-
6	SIM	1
7	SIM	2
8	SIM	1
9	SIM	2
10	SIM	-
11	SIM	-
12	SIM	2
13	SIM	3
14	SIM	2
15	SIM	1
16	SIM	-
17	SIM	-
18	SIM	-
19	SIM	-



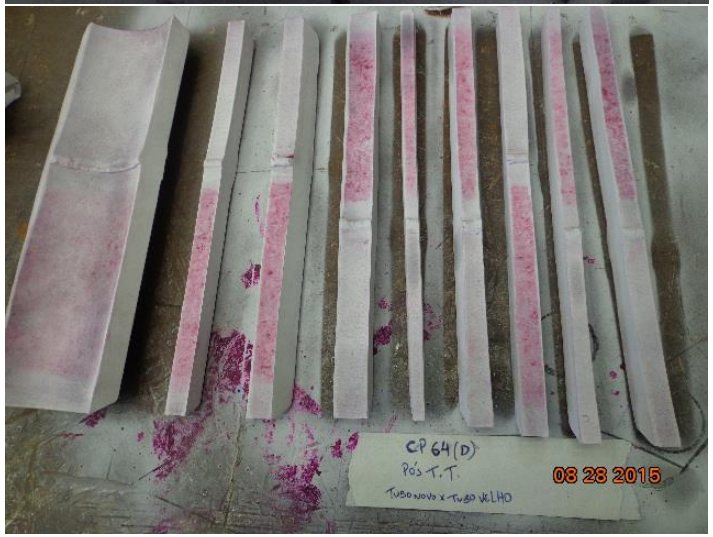
Soldagem: ASME SEC IX
Qualificação do Procedimento

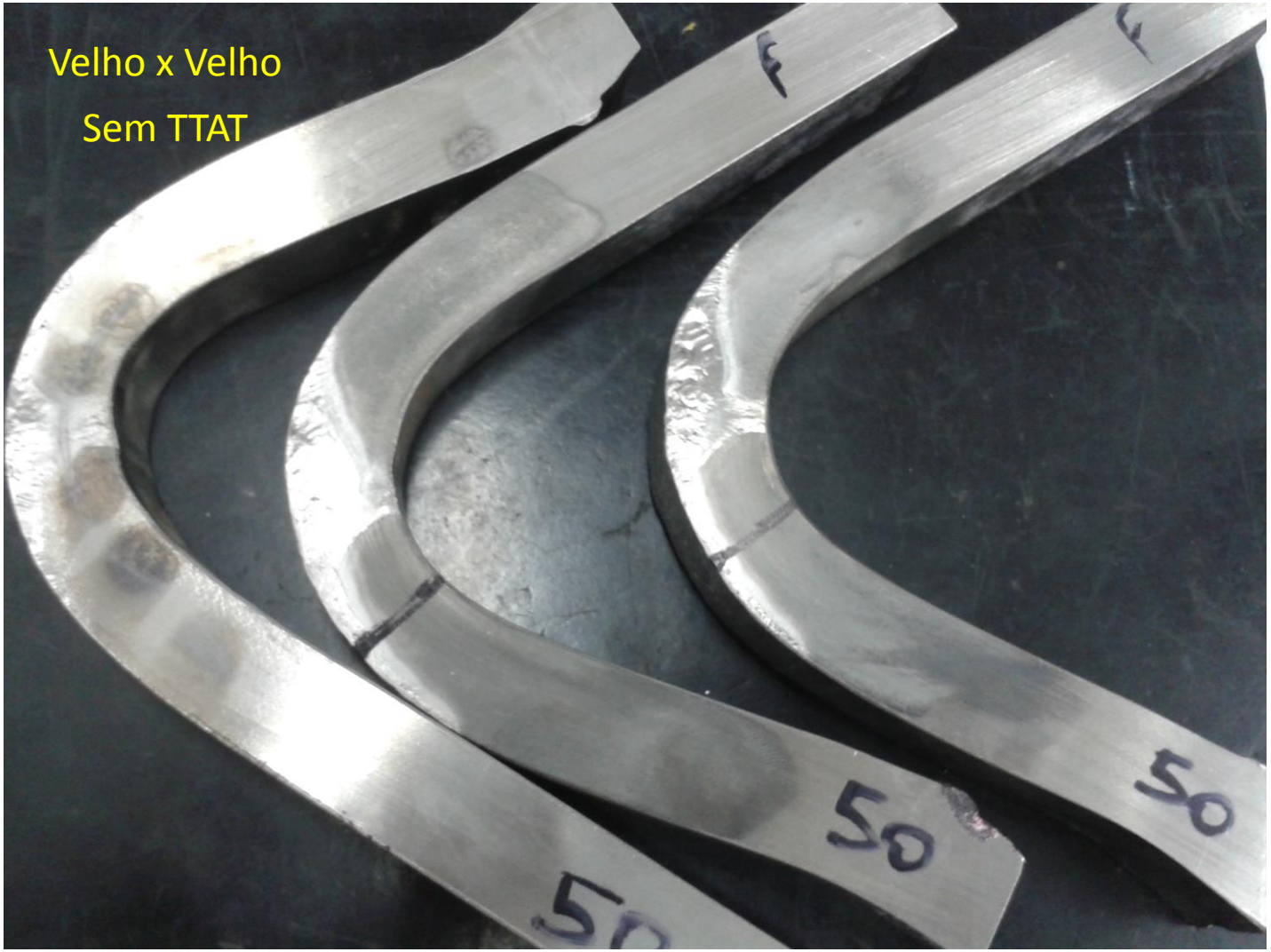
- Ensaio de Tração: 100% aprovados
- Ensaio de Dobramento: 7 tipos de CP, alternando material novo e envelhecido.

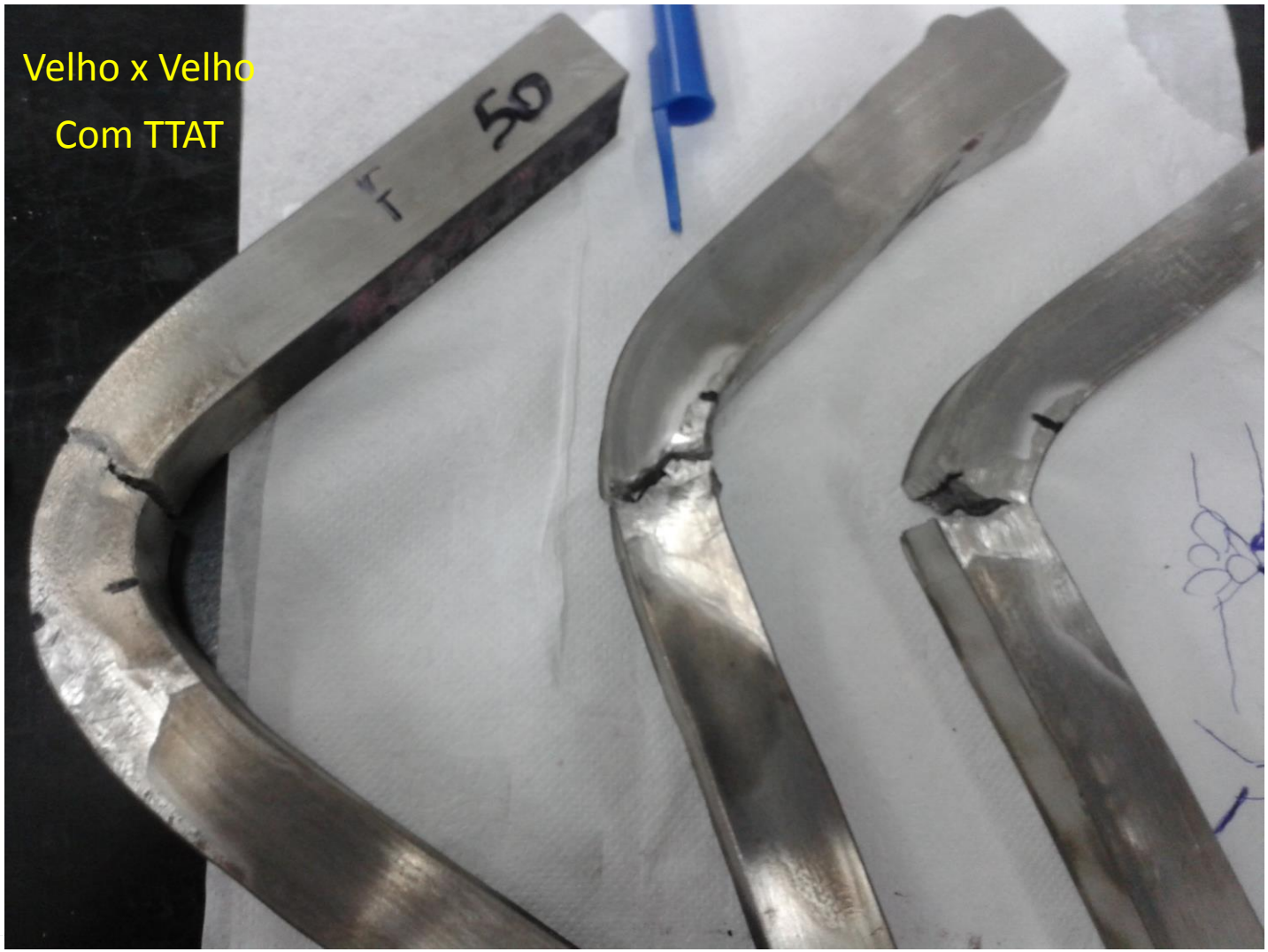
Condição do Tubo	Sem TTAT	Com TTAT
Velho x Velho	Aprovado	Reprovado
Velho x Novo	Aprovado	Reprovado
Novo x Novo	-	Aprovado
Velho com reparo	Aprovado	Reprovado

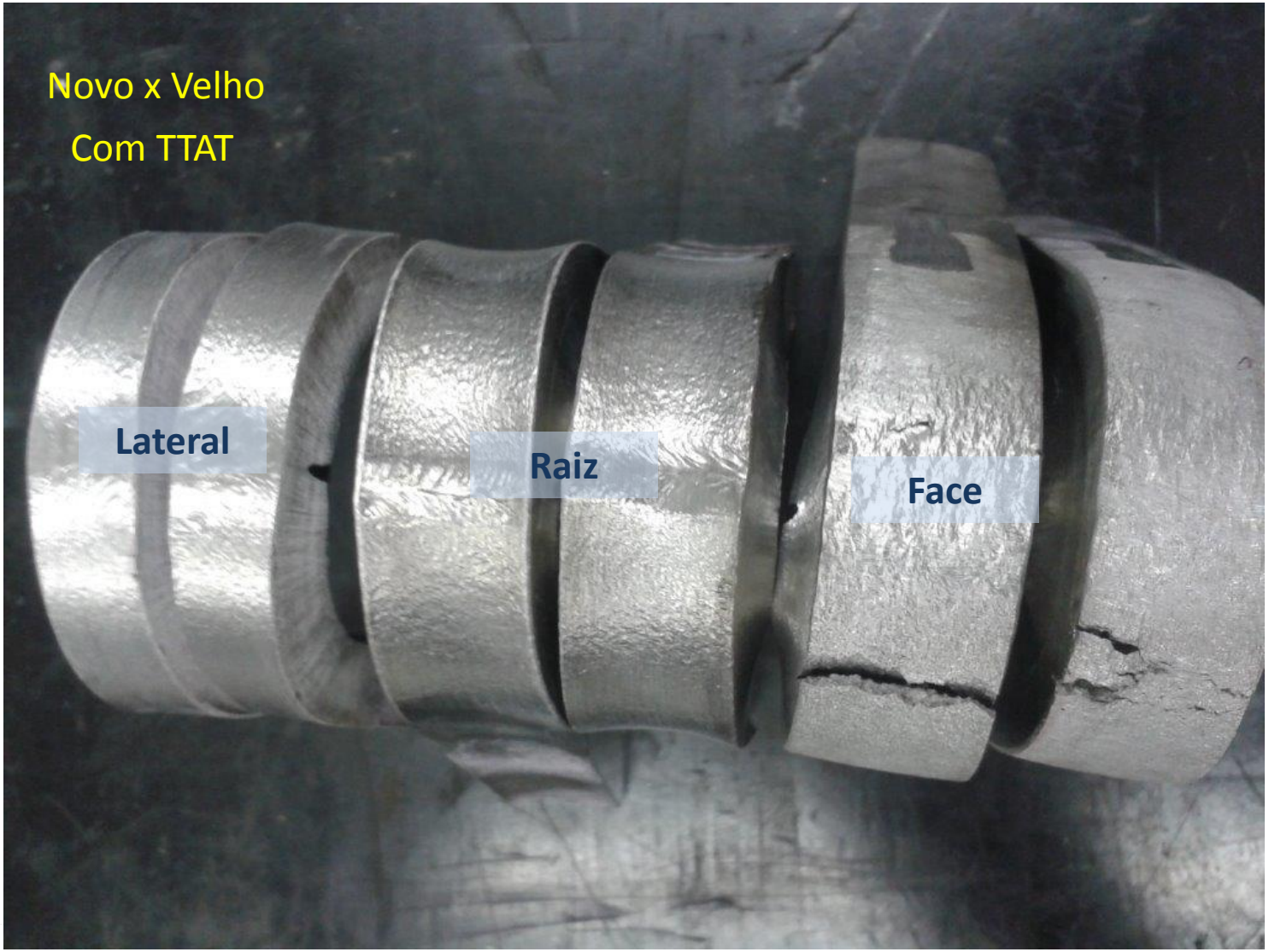
Preparação dos cps para qualificação do procedimento de soldagem

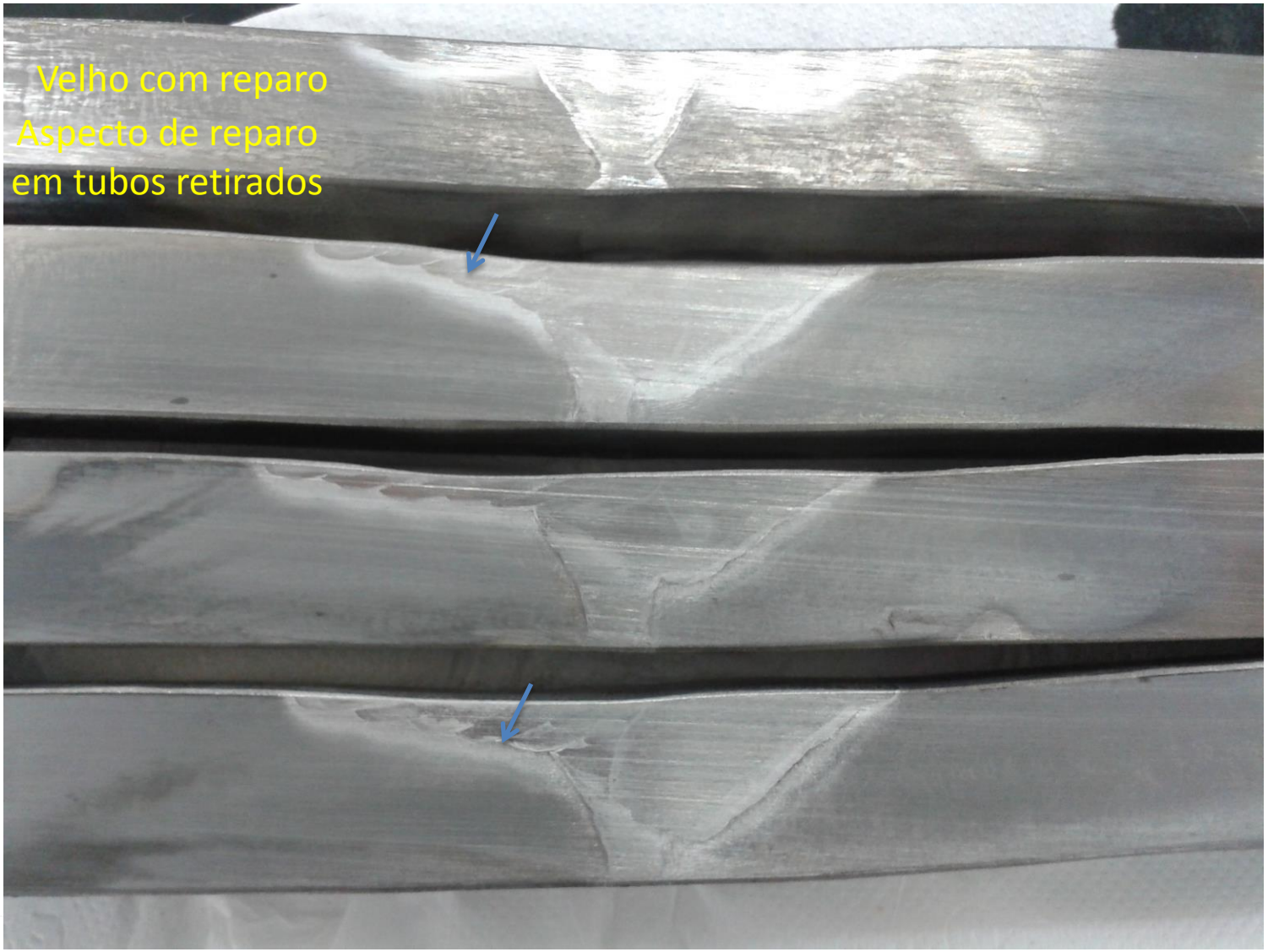
Preparação dos cps para qualificação do procedimento de soldagem



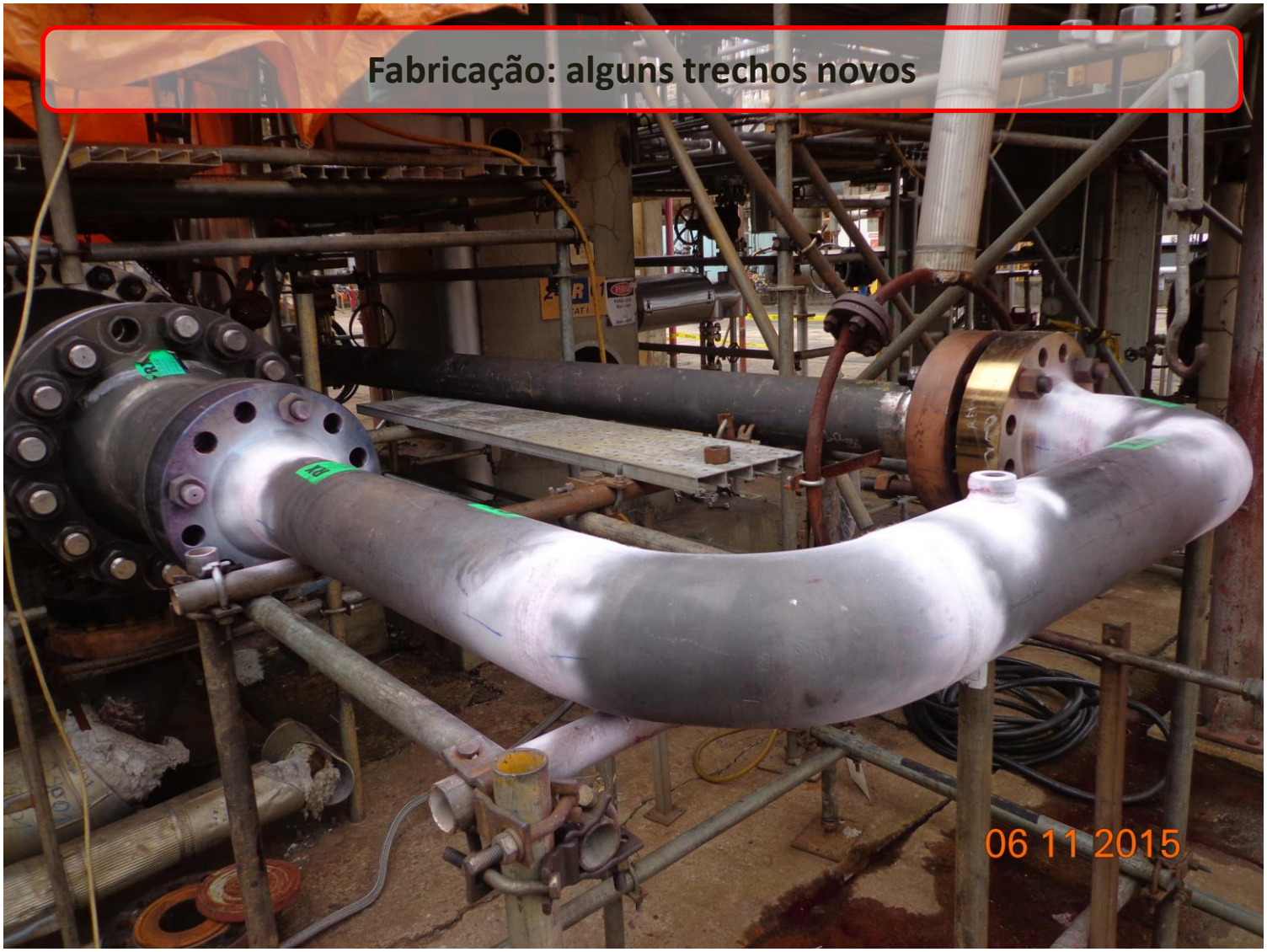

Velho x Velho
Sem TTAT
50
50
50


Velho x Velho
Com TTAT


Novo x Velho
Com TTAT
Lateral
Raiz
Face

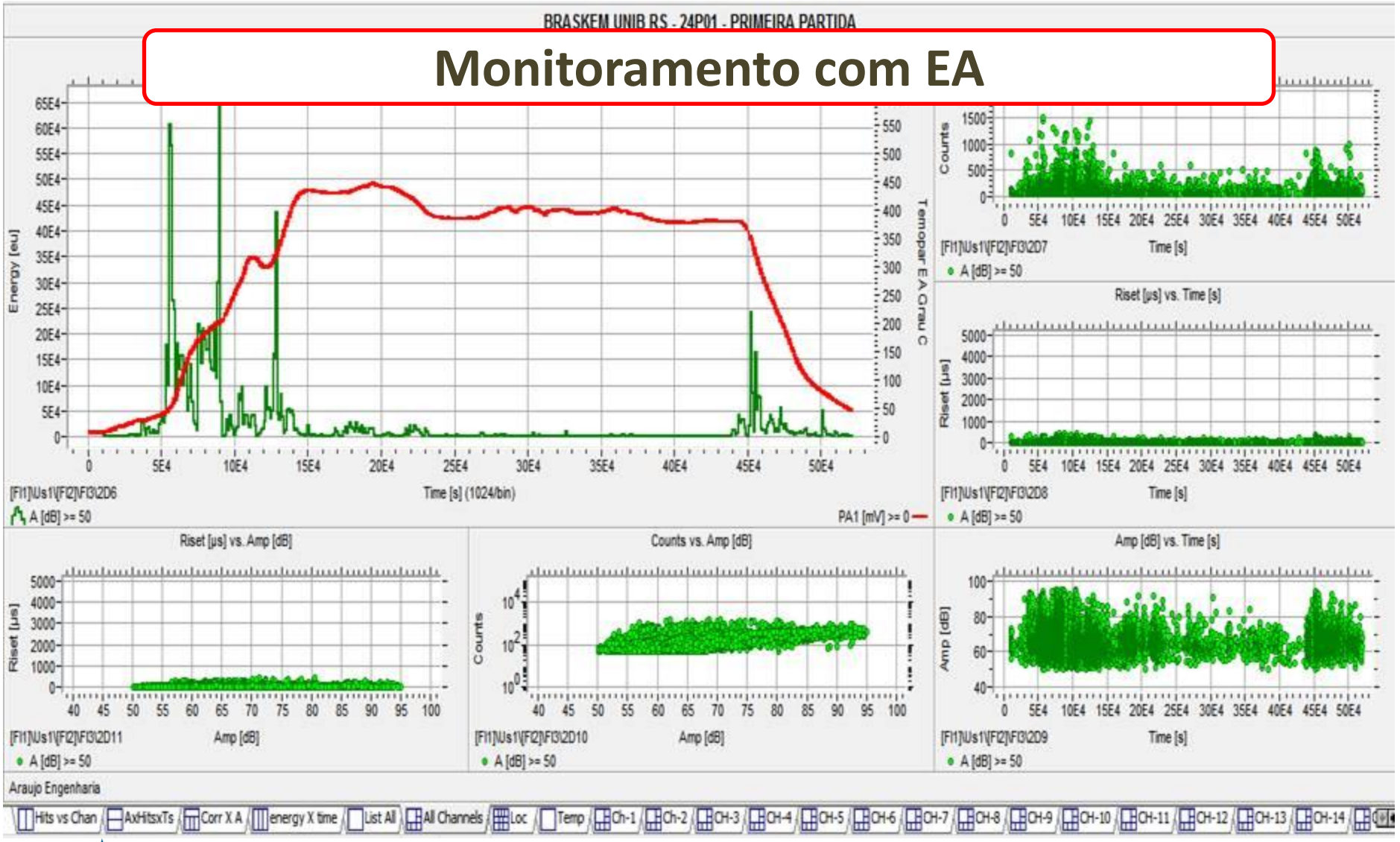

Velho com reparo
Aspecto de reparo
em tubos retirados

Fabricação: alguns trechos novos


Fabricação: alguns trechos novos
06 11 2015

Reparos: curva nova x tubo velho

Monitoramento com EA



Recomendações

- Operar no máximo 2 anos (até 2017) com a solução temporária;
- Adquirir e substituir as tubulações;
- Soldagem com TTAT;
- Redução do número de ciclos de partida e parada;
- Emissão acústica mandatória nos ciclos;
- Inspeção das soldas entre ciclos.