

## Trabalho EPS

## Dados:

EPS nº 35

Material A: SA 516 Gr 60

Espessura da chapa: 1 ¼" (43,5mm)

Material B: SA 106 Gr B

Espessura tubo: 12" STD (9,53mm DN 300mm)

Processo de Soldagem: FCAW

## Requisito de Projeto

Equipamento sujeito a H<sub>2</sub>S, junta de topo

- Introdução

Este trabalho busca abordar soluções baseadas no ASME IX para uma situação problema. Tal situação pode comumente acontecer na prática e o especialista técnico em soldagem tem que estar preparado para discutir tecnicamente e avaliar criticamente os aspectos de uma junta, no que condiz a seus aspectos de soldabilidade. Abordamos os pontos mais importantes e a conclusão do trabalho foi a elaboração de uma EPS teórica.

## Dados Material Chapa

- Composição Química

ASME II Parte C → SA-516 → SA 516 Gr 60

TABLE 1  
CHEMICAL REQUIREMENTS

Elements	Composition, %			
	Grade 55 [Grade 380]	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max <sup>(A), (B)</sup> :				
½ in. [12.5 mm] and under	0.18	0.21	0.24	0.27
Over ½ in. to 2 in. [12.5 to 50 mm], incl	0.20	0.23	0.26	0.28
Over 2 in. to 4 in. [50 to 100 mm], incl	0.22	0.25	0.28	0.30
Over 4 to 8 in. [100 to 200 mm], incl	0.24	0.27	0.29	0.31
Over 8 in. [200 mm]	0.26	0.27	0.29	0.31
Manganese <sup>(B)</sup> :				
½ in. [12.5] and under:				
Heat analysis	0.60–0.90	0.60–0.90 (C)	0.85–1.20	0.85–1.20
Product analysis	0.55–0.98	0.55–0.98 (C)	0.79–1.30	0.79–1.30
Over ½ in. [12.5 mm]:				
Heat analysis	0.60–1.20	0.85–1.20	0.85–1.20	0.85–1.20
Product analysis	0.55–1.30	0.79–1.30	0.79–1.30	0.79–1.30
Phosphorus, max <sup>(A)</sup>	0.035	0.035	0.035	0.035
Sulfur, max <sup>(A)</sup>	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45

NOTES:

(A) Applies to both heat and product analyses.

(B) For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50% by heat analysis and 1.60% by product analysis.

(C) Grade 60 plates ½ in. [12.5 mm] and under in thickness may have 0.85–1.20% manganese on heat analysis, and 0.79–1.30% manganese on product analysis.

ASME IX → Artigo IV → QW-422

Pnumber = 1

10) QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONTD)  
Grouping of Base Metals for Qualification

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding		Brazing	ISO 15608 Group	Nominal Composition	Product Form
				P-No.	Group No.	P-No.			
A 514	E	K21604	110 (760)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate, 2½ in. (64 mm) max.
A 514	P	K21650	100 (690)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
A 514	P	K21650	110 (760)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate, 2½ in. (64 mm) max.
A 514	Q	...	100 (690)	11B	9	102	3.1	1.3Ni–1.3Cr–0.5Mo–V	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
A 514	Q	...	110 (760)	11B	9	102	3.1	1.3Ni–1.3Cr–0.5Mo–V	Plate, 2½ in. (64 mm) max.
SA-515	60	K02401	60 (415)	1	1	101	1.1	C	Plate
SA-515	65	K02800	65 (450)	1	1	101	1.1	C–Si	Plate
SA-515	70	K03101	70 (485)	1	2	101	1.1	C–Si	Plate
SA-516	55	K01800	55 (380)	1	1	101	1.1	C–Si	Plate
SA-516	60	K02100	60 (415)	1	1	101	1.1	C–Mn–Si	Plate
SA-516	65	K02403	65 (450)	1	1	101	1.1	C–Mn–Si	Plate
SA-516	70	K02700	70 (485)	1	2	101	1.1	C–Mn–Si	Plate
SA-517	F	K11576	115 (795)	11B	3	101	3.1	0.75Ni–0.5Cr–0.5Mo–V	Plate ≤ 2½ in. (64 mm)
SA-517	B	K11630	115 (795)	11B	4	101	3.1	0.5Cr–0.2Mo–V	Plate ≤ 1¼ in. (32 mm)
SA-517	A	K11856	115 (795)	11B	1	101	3.1	0.5Cr–0.25Mo–Si	Plate ≤ 1¼ in. (32 mm)
SA-517	E	K21604	105 (725)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.

Dados Material: Tubo

- Espessura e diâmetro nominal de acordo com a norma ASME B36.10

**Table 1 Dimensions and Weights of Welded and Seamless Wrought Steel Pipe (Cont'd)**

NPS [Note (1)]	Customary Units			Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	SI Units		
	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft				Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
12	12.750	0.312	41.48	...	...	300	323.8	7.92	61.70
12	12.750	0.330	43.81	...	30	300	323.8	8.38	65.19
12	12.750	0.344	45.62	...	...	300	323.8	8.74	67.91
12	12.750	0.375	49.61	STD	...	300	323.8	9.53	73.86

- Composição Química

**TABLE 1  
CHEMICAL REQUIREMENTS**

	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max <sup>A</sup>	0.25	0.30	0.35
Manganese	0.27–0.93	0.29–1.06	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	0.10	0.10	0.10
Chrome, max <sup>B</sup>	0.40	0.40	0.40
Copper, max <sup>B</sup>	0.40	0.40	0.40
Molybdenum, max <sup>B</sup>	0.15	0.15	0.15
Nickel, max <sup>B</sup>	0.40	0.40	0.40
Vanadium, max <sup>B</sup>	0.08	0.08	0.08

<sup>A</sup> For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to a maximum of 1.35%.

<sup>B</sup> These five elements combined shall not exceed 1%.

ASME IX → Artigo IV → QW-422

Pnumber = 1

**10) QW/QB-422 FERROUS/NONFERROUS P-NUMBERS  
Grouping of Base Metals for Qualification**

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Ferrous				Nominal Composition	Product Form
				Welding		Brazing			
				P- No.	Group No.	P-No.	ISO 15608 Group		
SA-36	...	K02600	58 (400)	1	1	101	11.1	C-Mn-Si	Plate, bar & shapes
SA-53	Type F	...	48 (330)	1	1	101	11.1	C	Furnace welded pipe
SA-53	Type S, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Smls. pipe
SA-53	Type E, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Resistance welded pipe
SA-53	Type E, Gr. B	K03005	60 (415)	1	1	101	11.1	C-Mn	Resistance welded pipe
SA-53	Type S, Gr. B	K03005	60 (415)	1	1	101	11.1	C-Mn	Smls. pipe
SA-105	...	K03504	70 (485)	1	2	101	11.1	C	Flanges & fittings
SA-106	A	K02501	48 (330)	1	1	101	1.1	C-Si	Smls. pipe
SA-106	B	K03006	60 (415)	1	1	101	11.1	C-Mn-Si	Smls. pipe
SA-106	C	K03501	70 (485)	1	2	101	11.1	C-Mn-Si	Smls. pipe

- Variáveis Essenciais do Processo FCAW

ASME IX → Artigo II → QW-250 → Tabela QW-255

QW-255  
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)  
Gas Metal-Arc Welding (GMAW and FCAW)

Paragraph	Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1 $\phi$ Groove design			X
	.4 – Backing			X
	.10 $\phi$ Root spacing			X
	.11 $\pm$ Retainers			X
QW-403 Base Metals	.5 $\phi$ Group Number		X	
	.6 $\bar{T}$ Limits		X	
	.8 $\phi$ $\bar{T}$ Qualified	X		
	.9 $\bar{t}$ Pass > 1/2 in. (13 mm)	X		
	.10 $\phi$ $\bar{T}$ limits (S. cir. arc)	X		
	.11 $\phi$ P-No. qualified	X		
QW-404 Filler Metals	.4 $\phi$ F-Number	X		
	.5 $\phi$ A-Number	X		
	.6 $\phi$ Diameter			X
	.12 $\phi$ Classification		X	
	.23 $\phi$ Filler metal product form	X		
	.24 $\pm$ Supplemental $\phi$	X		
	.27 $\phi$ Alloy elements	X		
	.30 $\phi$ $\bar{t}$	X		
	.32 $\bar{t}$ Limits (S. cir. arc)	X		
.33 $\phi$ Classification			X	
QW-405 Positions	.1 + Position			X
	.2 $\phi$ Position		X	
	.3 $\phi$ $\updownarrow$ Vertical welding			X

QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	∅ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	∅ PWHT	X		
	.2	∅ PWHT (T & T range)		X	
	.4	T Limits	X		

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-408 Gas	.1	± Trail or ∅ comp.			X
	.2	∅ Single, mixture, or %	X		
	.3	∅ Flow rate			X
	.5	± or ∅ Backing flow			X
	.9	- Backing or ∅ comp.	X		
	.10	∅ Shielding or trailing	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.2	∅ Transfer mode	X		
	.4	∅ Current or polarity		X	X
	.8	∅ I & E range			X
QW-410 Technique	.1	∅ String/weave			X
	.3	∅ Orifice, cup, or nozzle size			X
	.5	∅ Method cleaning			X
	.6	∅ Method back gouge			X
	.7	∅ Oscillation			X
	.8	∅ Tube-work distance			X
	.9	∅ Multiple to single pass/side		X	X
	.10	∅ Single to multiple electrodes		X	X
	.15	∅ Electrode spacing			X
	.25	∅ Manual or automatic			X
.26	± Peening			X	
.64	Use of thermal processes		X		

Legend:

+ Addition      > Increase/greater than      ↑ Uphill      ← Forehand      ∅ Change  
 - Deletion      < Decrease/less than      ↓ Downhill      → Backhand

- Necessidade de TTAT na Qualificação de Procedimento

Consultando

ASME VIII Div I → UW-2

No trecho abaixo o ASME identifica a necessidade de TTAT para equipamentos com requisitos de H<sub>2</sub>S, os parâmetros do TTAT são tomados de acordo com o UCS-56.

(2) When the thickness at welded joints exceeds  $\frac{5}{8}$  in. (16 mm) for carbon (P-No. 1) steels and for all thicknesses for low alloy steels (other than P-No. 1 steels), postweld heat treatment is required. For all other material and in any thickness, the requirements for postweld heat treatment shall be in conformance with the applicable Subsections of this Division. See also U-1(g), UG-16(b), and UCS-56.

- Dados do Corpo de Prova

QW-451.1  
GROOVE-WELD TENSION TESTS AND TRANSVERSE-BEND TESTS

Thickness $T$ of Test Coupon, Welded, in. (mm)	Range of Thickness $T$ of Base Metal, Qualified, in. (mm) [Notes (1) and (2)]		Maximum Thickness $t$ of Deposited Weld Metal, Qualified, in. (mm) [Notes (1) and (2)]	Type and Number of Tests Required (Tension and Guided-Bend Tests) [Note (2)]				
	Min.	Max.		Tension, QW-150	Side Bend, QW-160	Face Bend, QW-160	Root Bend, QW-160	
Less than $\frac{1}{16}$ (1.5)	$T$	$2T$	$2t$	2	...	2	2	
PFI	$\frac{1}{16}$ to $\frac{3}{16}$ (1.5 to 10), incl.	$\frac{1}{16}$ (1.5)	$2T$	$2t$	2	Note (5)	2	2
	Over $\frac{3}{16}$ (10), but less than $\frac{3}{8}$ (19)	$\frac{3}{16}$ (5)	$2T$	$2t$	2	Note (5)	2	2
	$\frac{3}{8}$ (19) to less than $1\frac{1}{2}$ (38)	$\frac{3}{8}$ (5)	$2T$	$2t$ when $t < \frac{3}{8}$ (19)	2 [Note (4)]	4	...	...
	$\frac{3}{4}$ (19) to less than $1\frac{1}{2}$ (38)	$\frac{3}{4}$ (5)	$2T$	$2T$ when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
	$1\frac{1}{2}$ (38) to 6 (150), incl.	$\frac{3}{8}$ (5)	8 (200) [Note (3)]	$2t$ when $t < \frac{3}{8}$ (19)	2 [Note (4)]	4	...	...
	$1\frac{1}{2}$ (38) to 6 (150), incl.	$\frac{3}{8}$ (5)	8 (200) [Note (3)]	8 (200) [Note (3)] when $t \geq \frac{3}{8}$ (19)	2 [Note (4)]	4	...	...
	Over 6 (150)	$\frac{3}{8}$ (5)	1.33T	$2t$ when $t < \frac{3}{8}$ (19)	2 [Note (4)]	4	...	...
	Over 6 (150)	$\frac{3}{8}$ (5)	1.33T	1.33T when $t \geq \frac{3}{8}$ (19)	2 [Note (4)]	4	...	...

NOTES:

- (1) The following variables further restrict the limits shown in this table when they are referenced in QW-250 for the process under consideration: QW-403.9, QW-403.10, QW-404.32, and QW-407.4. Also, QW-202.2, QW-202.3, and QW-202.4 provide exemptions that supersede the limits of this table.
- (2) For combination of welding procedures, see QW-200.4.
- (3) For the SMAW, SAW, GMAW, PAW, and GTAW welding processes only; otherwise per Note (1) or  $2T$ , or  $2t$ , whichever is applicable.
- (4) See QW-151.1, QW-151.2, and QW-151.3 for details on multiple specimens when coupon thicknesses are over 1 in. (25 mm).
- (5) Four side-bend tests may be substituted for the required face- and root-bend tests, when thickness  $T$  is  $\frac{3}{8}$  in. (10 mm) and over.

De acordo com a tabela acima temos que encontrar a espessura ideal do corpo de prova que atenda a situação de campo. Neste caso utilizaremos corpo de prova com espessura de 22mm.

- Parâmetros do TTAT

De acordo com UCS-56, vamos determinar o parâmetro de tratamento térmico de alívio de tensões para uma junta de topo com espessura de 22mm.

- ➔ Taxa de aquecimento: 222°C/h
- ➔ Taxa de resfriamento: 280°C/h
- ➔ Temperatura de patamar: 595°C
- ➔ Tempo de tratamento: 53"

- Escolha do Metal de Adição

Em função do material a ser soldado e da resistência a tração desses materiais, temos o subsidio para escolha do consumível de soldagem. Nesse caso utilizaremos o eletrodo da especificação SFA 5.20, classificação E71T-1C

SFA-5.20 MECHANICAL PROPERTY REQUIREMENTS

AWS Classification(s)	Tensile Strength, ksi	Minimum Yield Strength <sup>a</sup> , ksi	Minimum % Elongation <sup>b</sup>	Minimum Charpy V-Notch Impact Energy
E7XT-1C, -1M	70-95	58	22	20 ft-lbf at 0°F
E7XT-2C <sup>c</sup> , -2M <sup>c</sup>	70 min.	Not Specified	Not Specified	Not Specified
E7XT-3 <sup>c</sup>	70 min.	Not Specified	Not Specified	Not Specified
E7XT-4	70-95	58	22	Not Specified
E7XT-5C, -5M	70-95	58	22	20 ft-lbf at -20°F
E7XT-6	70-95	58	22	20 ft-lbf at -20°F
E7XT-7	70-95	58	22	Not Specified
E7XT-8	70-95	58	22	20 ft-lbf at -20°F
E7XT-9C, -9M	70-95	58	22	20 ft-lbf at -20°F
E7XT-10 <sup>c</sup>	70 min.	Not Specified	Not Specified	Not Specified
E7XT-11	70-95	58	20 <sup>d</sup>	Not Specified
E7XT-12C, -12M	70-90	58	22	20 ft-lbf at -20°F
E6XT-13 <sup>c</sup>	60 min.	Not Specified	Not Specified	Not Specified
E7XT-13 <sup>c</sup>	70 min.	Not Specified	Not Specified	Not Specified
E7XT-14 <sup>c</sup>	70 min.	Not Specified	Not Specified	Not Specified
E6XT-G	60-80	48	22	Not Specified
E7XT-G	70-95	58	22	Not Specified
E6XT-GS <sup>c</sup>	60 min.	Not Specified	Not Specified	Not Specified
E7XT-GS <sup>c</sup>	70 min.	Not Specified	Not Specified	Not Specified

- Gás de Proteção

De acordo com a escolha do metal de adição definimos em SFA 5.32 a qualidade e especificação do gás utilizado, nesse caso CO<sub>2</sub>.

TABLE 1  
GAS TYPE, PURITY, AND DEW POINT REQUIREMENTS FOR SHIELDING GAS COMPONENTS

Gas	AWS Classification	Product State	Minimum Purity, %	Maximum Moisture, <sup>(1)</sup> ppm	Dew Point Maximum Moisture at 1 Atmosphere		CGA Class
					°F	°C	
Argon	SG-A	Gas	99.997	10.5	-76	-60	Type I G-11.1 Grade C
		Liquid	99.997	10.5	-76	-60	Type II G-11.1 Grade C
Carbon Dioxide	SG-C	Gas	99.8	32	-60	-51	G-6.2 Grade H
		Liquid	99.8	32	-60	-51	G-6.2 Grade H
Helium	SG-He	Gas	99.995	15	-71	-57	Type I G-9.1 Grade L
		Liquid	99.995 <sup>(2)</sup>	15	-71	-57	Type II G-9.1 Grade L
Hydrogen	SG-H	Gas	99.95	32	-60	-51	Type I G-5.3 Grade B
		Liquid	99.995 <sup>(3)</sup>	32	-60	-51	Type II G-5.3 Grade A
Nitrogen	SG-N	Gas	99.9	32	-60	-51	Type I G-10.1 Grade F
		Liquid	99.998	4	-90	-68	Type II G-10.1 Grade L
Oxygen	SG-O	Gas	99.5	Not Applicable	-54	-48	Type I G-4.3 Grade B
		Liquid	99.5	Not Applicable	-82	-63	Type II G-4.3 Grade B

- Determinação de faixa de Espessura

Consultando QW-404.30 temos que a máxima espessura depositada pelo metal de adição para juntas de topo é de 44mm.

- A-number

De acordo com a composição química do material de base determinamos o A-number, no nosso caso utilizaremos o A-number1;

QW-442  
A-NUMBERS  
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)]					
		C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	...	...	...	1.60	1.00

- Forma do Metal de adição

De acordo com QW-404.23, temos que a forma do metal de adição é arame tubular com fluxo interno;

**QW-404.23** A change from one of the following filler metal product forms to another:  
(a) bare (solid) or metal cored  
(b) flux cored  
(c) flux coated solid or metal cored  
(d) powder

- Modo de Transferência

Consultando QW-409.2 verificamos que somente poderemos utilizar os modos de transferência globular e spray;