



HEAT EXCHANGER MATERIALS SPECIFICATION

FOR THE

CARTAGENA REFINERY EXPANSION PROJECT

CB&I CONTRACT NO. 166000

Document No: 000-SP-ME07-0006

Information Class: ☐ Confidential ☒ Business ☐ Public

Revision Number	Revision Date	Revision Description	Prepared By:	Checked By:	Approved By:
A	26-Mar-08	ISSUED FOR REVIEW & COMMENT	RSB	QV	N/A
0	29-Apr-08	ISSUED FOR DESIGN	RSB	QV	KRS
1	07-Aug-08	ISSUED FOR DESIGN	GC	QV	IAR
2	14-Aug-08	ISSUED FOR DESIGN	GC	TBH	IAR
3	08-Sep-08	ISSUED FOR DESIGN	GC	TBH	IAR
4	16-Sep-09	ISSUED FOR DESIGN	GC	SA	HGT
5	10-May-11	ISSUED FOR CONSTRUCTION	BT	KDB	GAD

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 2 of 22

TABLE OF CONTENTS

1	INTRODUCTION	3
2	REFERENCES	3
	2.1 CB&I Documents	3
	2.2 American Institute of Steel Construction (AISC)	3
	2.3 American Society of Mechanical Engineers (ASME)	3
	2.4 American Petroleum Institute (API)	3
	2.5 American Society for Testing and Materials (ASTM)	4
	2.6 American Welding Society (AWS)	4
	2.7 National Association of Corrosion Engineers (NACE)	4
3	DEFINITIONS	5
4	REQUIREMENTS	5
	4.1 Materials	5
	4.2 Material Selection	8
	4.3 Metal Temperatures	12
	4.4 Material Selection for Minimum Design Metal Temperatures (MDMT)	12
	4.5 Fresh Cooling Water Service	18
5	APPENDICES	19

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 3 of 22

1 INTRODUCTION

This specification defines the major materials for heat transfer equipment. Materials are specified by nominal composition, generic name or trade name on the Heat Exchanger Data Sheet. All materials shall be new. Substitution of materials will not be allowed without the Purchaser's written approval.

2 REFERENCES

The following documents are referenced herein and form part of the Order. Additional CB&I documents, when applicable, will be listed on the Requisition. The issue revisions of CB&I documents shall be as specified in the Requisition. Current editions of the industry standards including all mandatory addenda in effect at the time of the order shall apply unless otherwise indicated.

2.1 CB&I Documents

2.1.1 166000-000-SP-MU10-0001 "General Welding Requirements"

2.2 American Institute of Steel Construction (AISC)

2.2.1 AISC "Manual of Steel Construction, Allowable Stress Design"

2.3 American Society of Mechanical Engineers (ASME)

2.3.1 ASME Boiler and Pressure Vessel Code and referenced standards listed in ASME Section VIII, Table U-3.

2.3.2 Section II, "Materials"

- Part A - "Ferrous Material Specifications"
- Part B - "Nonferrous Material Specifications"

2.3.3 Section VIII, "Pressure Vessels" Division 1 and Division 2

2.3.4 ASME B16.5, "Pipe Flanges and Flanged Fittings NPS ½ through NPS 24"

2.3.5 ASME B16.47, "Large Diameter Steel Flanges NPS 26 through NPS 60"

2.3.6 ASME B31.3, "Process Piping"

2.4 American Petroleum Institute (API)

2.4.1 API SPEC 5L, "Line Pipe"

2.4.2 API STD 617, "Axial and Centrifugal Compressors and Expander-Compressors for Petroleum, Chemical and Gas Industry Services"

2.4.3 API RP 934-A, "Materials and Fabrication Requirements for 2¼Cr-1Mo, 2¼Cr-1Mo-¼V, 3Cr-1Mo, and 3Cr-1Mo-¼V Steel Heavy Wall Pressure Vessels for High-temperature, High-pressure Hydrogen Service"

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 4 of 22

- 2.4.4 API RP 934-C, "Materials and Fabrication Requirements for 1¼ Cr-½Mo & 3Cr-1Mo Steel Heavy Wall Pressure Vessels for High-pressure Hydrogen Service Operating at or Below 825 °F (441 °C)"
- 2.4.5 API RP 941, "Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants"
- 2.4.6 API RP 945, "Avoiding Environmental Cracking in Amine Units"
- 2.5 American Society for Testing and Materials (ASTM)
 - 2.5.1 ASTM Material Standard Specifications
 - 2.5.2 A-380-06: Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
- 2.6 American Welding Society (AWS)
 - 2.6.1 AWS D1.1/D1.1M, "Structural Welding Code - Steel"
- 2.7 National Association of Corrosion Engineers (NACE)
 - 2.7.1 MR0103, Standard Material Requirements: "Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments"
 - 2.7.2 RP0472, Standard Recommended Practice: "Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments".

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 5 of 22

3 DEFINITIONS

DSS	DUPLEX STAINLESS STEEL
SDSS	SUPER DUPLEX STAINLESS STEEL
CARBON STEEL	STEEL OF C-SI AND C-MN CHEMISTRIES
LOW ALLOY STEEL	STEEL OF CR-MO, AND MN-MO CHEMISTRIES
HIGH ALLOY STEEL	AUSTENITIC STAINLESS STEELS (E.G., 18-8 CR-NI)
NON-FERROUS MATERIAL	INDICATES ALUMINIUM, TITANIUM, ZIRCONIUM OR SIMILAR
LOW NICKEL STEEL	INDICATES LOW NICKEL (E.G., 2 ½ THRU 9%) CHEMISTRIES
PRESSURE VESSELS	VESSELS OR EXCHANGERS AS DEFINED BY ASME SECTION VIII

4 REQUIREMENTS

4.1 Materials

4.1.1 Pressure Part Materials

4.1.1.1 Tubing, pipe, plate and forging materials for fabrication/assembly of Heat Exchangers shall be selected for the design conditions and environmental exposure constraints and shall conform to the specifications and grades provided within Table III of this specification.

4.1.1.2 The requirements listed in the API and NACE references listed in section 2 shall apply when stated in this specification or on the Exchanger Data Sheet.

4.1.2 Tubes

4.1.2.1 Welded tubing shall pass a non-destructive electric test in accordance with ASME SA-450. The test shall be performed after the final heat treatment of the tubing.

4.1.2.2 Austenitic stainless steel U-tubes shall be only low carbon containing grades such as 304L and 316L or chemically stabilized grades Type 321 and Type 347 stainless steel and heat treated to relieve residual stresses and effects of localized work hardening caused by hot or cold bending of tubes. The solution annealing shall be performed by induction or resistance heating methods in accordance with Section 8 of ASME SA-688.

4.1.3 Lining Cladding and Weld Overlay

4.1.3.1 The minimum thickness of clad and weld overlay are as follows:

Tubesheet: Shellside face 3/8" (9.5 mm). Channel side 5/16" (7.8mm) when tubes are expanded only, and 1/8" (3.2 mm) when tubes are welded to the tubesheet. All

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 6 of 22

surfaces, other than in the area into which tubes are expanded, 1/8" (3.2mm). Gasket grooves 1/8" (3.2mm) below the final machined depth.

Shell, channel, and nozzle 1/8" (3.2mm).

For weld overlay on the shell, channel, or nozzle, a composite of the top 1/8" (3.2mm) of the overlay material shall meet the chemistry requirements based on wet chemical analysis.

4.1.3.2 Lining shall be either integrally bonded cladding conforming to ASME SA-263, SA-264 or SA-265 or shall be weld overlay in accordance with 166000-000-SP-MU10-0001 "General Welding Requirements". Heat treatment for clad plate conforming to SA-263 and SA-264 shall be done at the mill.

4.1.3.3 Loose liners, strip liners or plug welded liners are not acceptable unless permitted otherwise on the Exchanger Data Sheet.

4.1.3.4 Welding of solid alloy nozzles on the clad plate or weld deposited main nozzle are prohibited due to thermal expansion on units with design temperature above 300 °F (149 °C). All attachments will have to be evaluated differently. However, as a general rule, this note is applicable.

4.1.4 Bolting

Bolting shall be selected from Table I. Table II defines the bolting types specified in Table I.

Table I – Type of Bolting for Pressure Connections

Materials Joined	Metal Temperature Range (1)											
	°F	(-320)- (-151)	(-150)- (-51)	(-50)- (-21)	(-21)- 100	101- 400	401- 450	451- 850	851- 1000	1001- 1100	1101- 1200	1201- 1500
	°C	(-196)- (-102)	(-101)- (-46)	(-46)- (-29)	(-29)- 38	38- 204	205- 232	233- 454	455- 538	538- 593	594- 649	649- 816
Carbon Steel	-	-	L7	B7	B7	B7	B7	B7 (2)	-	-	-	-
Ferritic	-	-	-	B7	B7	B7	B7	B7 (2)	B16	B16 (5)	B5 OR 600(5)	-
Austenitic	-	B8 (3)	B8M2	B7	B7	B7	B7	B8 (3)	B8 (3)	HX (4)	HX (4)	HX (4)

NOTES TO TABLE I: (Numbers in parentheses refer to the following notes)

1. Consideration shall also be given to ambient temperatures before start-up.
2. Type B16 bolting may be used for temperatures exceeding 700 °F (371 °C).
3. Class 2, solution annealed and strain hardened.
4. Use of intermediate strength bolts (e.g., strain hardened stainless steel) requires:
 - a. Verification that the bolts can seat the gasket and maintain a sealed joint under expected operating conditions.

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 7 of 22

- b. Consideration of differential thermal expansion of bolting and flanges, where applicable.
5. Vendor may have option not to use B16 or B5 at hub to reduce flange thickness at above 1000°F.

Table II – Bolting Type

Bolting Type	Bolt Material (Generic)	UNS Number	ASTM Specifications	
			Bolts	Nuts
B5	5Cr	K50100	A193 Gr B5	A194 Gr 3
B7	Cr-Mo	G41400	A193 Gr B7	A194 Gr 2H
B7M	Cr-Mo	G41400	A193 Gr B7M (6)	A194 Gr 2HM, 7M (6)
B8	18Cr-8Ni	S30400	A193 Gr B8 Cl 2	A194 Gr 8TA
B8M	16Cr-12Ni-2Mo	S31600	A193 Gr B8M	A194 Gr B8MA
B8MA	16Cr-12Ni-2Mo	S31600	A193 Gr B8MA, Cl 1A (6)	A194 Gr B8MA (6)
B8M2	16Cr-12Ni-2Mo	S31600	A193 Gr B8M2	A194 Gr B8MA
B16	Cr-Mo-V	K14072	A193 Gr B16	A194 Gr 4 (3)
L7	Cr-Mo	G41400	A320 Gr L7	A194 Gr 4 (3)
L7M	Cr-Mo	G41400	A320 Gr L7M (6)	A194 Gr 2HM, 7M (6)
600	Alloy 600 Ni-Cr-Fe	N06600	B166 Gr 600 (1)	B166 Gr 600 (2)
HX	Hastelloy X Ni-Cr-Mo-Fe	-	SB-572-X ANN N06002 (4), (5)	SB-572-X ANN N06002 (4), (5)

NOTES TO TABLE II: (Numbers in parentheses refer to the following notes)

- Dimensions to SA-193.
- Dimensions to SA-194.
- SA 194 Gr 4 nuts shall be impact tested at -150 °F (-101 °C) in accordance with SA320 for design temperatures colder than -55 °F (-48 °C).
- ASME Material (SAXXX or SBXXX) shall be in accordance with ASME Section II, Part A or Part B.
- Design allowable stresses are to be in accordance with ASME Section VIII, Div 1 and IID.
- Common, acceptable bolting material per NACE MR0103.

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 8 of 22

4.1.5 Gaskets

4.1.5.1 Metal jackets of metal jacketed gaskets, except brass jacketed gaskets shall be annealed.

4.1.5.2 Solid flat metal gaskets and seal welded diaphragms shall have the following maximum Brinell Hardness:

- a. 90 for soft iron
- b. 120 for low carbon iron, low carbon steel and nickel.
- c. 125 for 67Ni-30Cu (Monel®).
- d. 130 for 5Cr-½Mo steel.
- e. 150 for 347SS
- f. 160 for 18Cr-8Ni steel and 16Cr-13Ni-3Mo steel.
- g. 150 for Inconel® 600.
- h. 150 for Inconel® 625.
- i. 215 for Titanium.

4.1.5.3 Composition or filler material for all gaskets other than nozzle flanges shall be flexible graphite, unless otherwise noted on the Heat Exchanger Data Sheet.

4.1.5.4 Nozzle flange gaskets shall be spiral wound flexitallic style CG.

4.1.5.5 If spiral wound flexitallic gaskets are provided for body flanges they shall be style CGI. Spiral wound gaskets are not recommended for the floating head.

4.1.5.6 If Kammprofile gaskets are provided, they shall be type PN with gasket factor of $y = 5,000$ and $m = 4$.

4.1.6 Contamination of Stainless Steel

Austenitic stainless steel for use in solid or clad forms shall be obtained from the mill free of iron contamination. Apply ASTM A-380-06 to minimize iron contamination of SS surface. If iron contamination is suspected, or a contamination was present and has not been properly removed, the company shall require a Copper Sulphate test is required per ASTM A-380-06 to validate the absence or presence of iron. The removal of iron contamination shall include non-harmful grinding wheels and/or SS wire brushes as required by A-380-06.

4.1.7 Bellows Expansion Joints

The material for the thin wall bellows in expansion joints is to be Alloy 625 LCF unless otherwise noted on the Data Sheet.

4.2 Material Selection

4.2.1 Materials specified as generic, by nominal composition or trade name on the Heat Exchanger Data Sheet shall be selected from Table III.

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 9 of 22

- 4.2.2 All material shall meet the Minimum Design Metal Temperature (MDMT) requirements as stated in Section 4.3 of this Specification. If a Minimum Design Temperature (MDT) is not given on the Exchanger Data Sheet, it shall be +20 °F (-6.6 °C).
- 4.2.3 Tie rods, spacers and tube supports shall be commercial quality material of nominal composition similar to baffle material.
- 4.2.4 Cast material is not permitted, except when provided as supplier standard closures on Hairpin Exchangers.

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 10 of 22

TABLE III – MATERIAL SELECTION

MATERIAL NAME OR NOMINAL ANALYSIS	PRESSURE PARTS UNS NUMBER				
	WELDED TUBES	SEAMLESS TUBES	PIPE	PLATE	FORGING
CS	SA-214 (2)* K01807	SA-179 (2)* K01200	SA-106-B K03006	SA-516-60, 65 OR 70 K02100, K02403, K02700	SA-266 GR 2 OR 4* (13) K03506, K03017
KCS	SA-214 (2, 11)*	SA-210-A1 OR C K02707, K035501 OR SA-179 (2, 11) *	SA-106-B K03006	SA-516-60, 65 OR 70 K02100, K02403, K02700	SA-266 GR 2 OR 4* (10, 13) K03506, K03017
1CR-½MO	-	SA-213-T12 K11562	SA-335-P12 K11562	SA-387-12 CL 1 OR 2 K11757	SA-336-F12 K11564
1¼CR-½MO	-	SA-213-T11 K11597	SA-335-P11 K11597	SA-387-11 CL 1 OR 2 K11789	SA-336-F11 CL 2 OR 3 K11572
2¼CR-1MO	-	SA-213-T22 K21590	SA-335-P22 K21590	SA-387-22 CL 1 OR 2 K21590	SA-336-F22 CL 1 OR 3 K21590
5CR-½MO	-	SA-213-T5 K41545	SA-335-P5 K41545	SA-387-5 CL 1 OR 2 K41545	SA-336-F5 OR F5A K41545/K42544
13CR	SA-268 TP410 S41000	SA-268 TP410 S41000	-	-	-
304	SA-249 TP304 S30400	SA-213 TP304 S30400	SA-312 TP304 S30400	SA-240 304 S30400	SA-336-F304 S30400
304L	SA-249 TP304L S30403	SA-213 TP304L S30403	SA-312 TP304L S30403	SA-240 304L S30403	SA-336 F304L S30403
304H	SA-249 TP304H S30409	SA-213 TP304H S30409	SA-312 TP304H S30409	SA-240 304H S30409	SA-336 TP304H S30409
316	SA-249 TP316 S31600	SA-213 TP316 S31600	SA-312 TP316 S31600	SA-240 316 S31600	SA-336-F316 S31600
316L	SA-249 TP316L S31603	SA-213 TP316L S31603	SA-312 TP316L S31603	SA-240 316L S31603	SA-336 F316L S31603
316H	SA-249 TP316H S31609	SA-213 TP316H S31609	SA-312 TP316H S31609	SA-240 316H S31609	SA-336 F316H S31609
317L	SA-249 TP317L S31703	SA-213 TP317L S31703	SA-312 TP317L S31703	SA-240 317L S31703	SA-336-F317L S31603
321	SA-249 TP321 S32100	SA-213 TP321 S32100	SA-312 TP321 S32100	SA-240 321 S32100	SA-336 F321 S32100
321H	SA-249 TP321H S32109	SA-213 TP321H S32109	SA-312 TP321H S32109	SA-240 321H S32109	SA-336 F321H S32109
347	SA-249 TP347 S34700	SA-213 TP347 S34700	SA-312 TP347 S34700	SA-240 347 S34700	SA-336 F347 S34700

 	HEAT EXCHANGER MATERIALS SPECIFICATION			Document No.: 000-SP-ME07-0006
				Revision: 5
				Date: 10-May-11
				Page: 11 of 22

347H	SA-249 TP347H S34709	SA-213 TP347H S34709	SA-312 TP347H S34709	SA-240 347H S34709	SA-336 F347H S34709
ALLOY 2205/2507 (12)	SA-789 S31803/S32750	SA-789 S31803/S32750	SA-790 S31803/S32750	SA-240 S31803/S32750	SA-182 F51/F53 S31803/S32750
NICKEL 200	-	SB-163 N02200	SB-161 N02200	SB-162 N02200	SB-160 N02200
NICKEL 201	-	SB-163 N02201	SB-161 N02201	SB-162 N02201	SB-160 N02201
ALLOY 400	-	SB-163 N04400	SB-165 N04400	SB-127 N04400	SB-564 N04400
ALLOY 600	SB-516 N06600	SB-163 N06600	SB-167 (6) N06600	SB-168 N06600	SB-564 N06600
ALLOY 601	-	SB-167 N06601	SB-167 N06601	SB-168 N06601	SB-166 N06601
ALLOY 625	SB-704 N06625	SB-444 N06625	SB-444 N06625	SB-443 N06625	SB-564 N06625
ALLOY 800	SB-515 N08800	SB-163 N08800	SB-407 (7) N08800	SB-409 N08800	SB-564 N08800
ALLOY 800H	SB-515 N08810	SB-163 N08810	SB-407 (8) N08810	SB-409 N08810	SB-564 N08810
ALLOY 800HT	-	SB-163 N08811	SB-407 N08811	SB-409 N08811	SB-564 N08811
ALLOY 825	SB-704 N08825	SB-163 N08825	SB-423 N08825	SB-424 N08825	SB-564 N08825
ALLOY C-276 UNS N10276	SB-626 N10276	SB-622 N10276	SB-622 N10276	SB-575 N10276	SB-564 N10276
INHIBITED ADMIRALTY	-	SB-111 (3, 4, 5)	-	SB-171 (3)	-
90-10 CU-NI	-	SB-111 C70600 (4, 5)	SB-466 C70600	SB-171 C70600	-
70-30 CU-NI	-	SB-111 C71500 (5)	SB-466 C71500	SB-171 C71500	-
NRB	-	-	-	SB-171, C46500	-
TITANIUM	SB-338 GRADES 2, 3 OR 7 R50400, R50550, R52400	SB-338 GRADES 2, 3 OR 7 R50400, R50550, R52400	SB-861 GRADES 2, 3 OR 7 R50400, R50550, R52400	SB-265 GRADES 2, 3 OR 7 (9) R50400, R50550, R52400	-

NOTES TO TABLE III: (Numbers in parenthesis refer to the following numbered notes.)

1. The material shown for forgings applies to all girth flanges, tubesheets, flat covers and nozzles with integrally forged necks. Material for ASME B16.5 and ASME B16.47 flanges shall be selected from the applicable standard.
2. SA-334 Gr 6 may be used to 650 °F (343 °C).
3. Inhibited Admiralty tubes and plate shall be UNS Number C44300, C44400 or C44500.
4. Integrally finned tubes shall be in accordance with SB-359.
5. U-tubes shall be in accordance with SB-395.
6. SB-517 (N06600) welded pipe may be used.

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 12 of 22

7. SB-514 (N08800) welded pipe may be used.
8. SB-514 (N08810) welded pipe may be used.
9. Grade 2 is the primary preference for cladding however, Grade 1 material may be used for cladding material where the vendor has proven experience for the application.
10. Supplement S8 of SA-788 is mandatory.
11. SA-214* or SA-179* cannot be specified as "killed CS" because the ASME specifications for SA-214 and SA-179 says supplying any element other than those listed is not permitted.
12. Heat Treatment, welding and upper design temperatures require special attention for DSS and SDSS alloys.
13. *SA-214, *SA-179, *SA-266 Grade 4* shall not be used for ASME Section I materials.

4.3 Metal Temperatures

- 4.3.1 The Minimum Design Temperature (MDT) shall be considered in the selection of materials for pressure retaining parts and structural attachments to exchangers. The MDT will be noted on the Exchanger Data Sheet or in this Specification.
- 4.3.2 The Minimum Design Metal Temperature (MDMT) for the exchanger shall be based on the MDT provided by the Purchaser. The MDMT to be stamped on the exchanger nameplate shall not be warmer than the MDT provided by the Purchaser.
- 4.3.3 An exchanger may have more than one MDT specified by the Purchaser. Parts subject to the conditions of both sides of the exchanger i.e., tubesheet, tubes, floating head, etc., shall have a MDT equal to the coldest temperature condition.
- 4.3.4 If there is a possible need to conduct a hydrotest (either during fabrication or in subsequent service) at a temperature colder than 50 °F (10 °C), then the MDMT shall be at least 30 oF (16.7 °C) colder than the anticipated hydrotest water temperature.

4.4 Material Selection for Minimum Design Metal Temperatures (MDMT)

- 4.4.1 This section covers the material selection toughness requirements that are independent of corrosion considerations for services of steel used in exchangers, and structural steel in the design metal temperature service range between -425 °F and 59 °F (-254 °C and 15 °C).
- 4.4.2 When the material limitations and impact testing requirements of the industry standards and codes are more stringent than those specified in this specification, the requirements of the industry standards and codes shall govern.
- 4.4.3 Material selection for the minimum design metal temperature shall be in accordance with the applicable code of construction and this specification.

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 13 of 22

4.4.4 Pressure Containing Equipment and Components

4.4.4.1 Material selection for pressure containing equipment and components must as a minimum be in accordance with the applicable ASME Code. Table V lists recommended minimum ASTM material selections and cautionary or explanatory notes.

4.4.4.2 SA-350-LF2 is not acceptable for tube sheets, flat channel covers or non standard flanges (all except ASME B16.5 and B16.47, and standard long welding necks) see Table V, Note 9.

4.4.4.3 Carbon and low alloy steels, if not qualified by impact testing, shall not be used for pressure containment at a MDMT colder than -20 °F (-28.8 °C) unless specifically allowed by the applicable Code.

4.4.4.4 Carbon and low alloy steels used for pressure containing components or essential for structural support with operating temperatures below -55 °F (-48.3 °C) shall be impact test qualified in accordance with the applicable material specification and/or design code.

4.4.5 Non-Pressure Parts Welded to Pressure Parts

4.4.5.1 The material for non-pressure parts directly welded to high alloy or low nickel alloy steel pressure parts shall be in accordance with the material standards listed in Table V according to temperature for the type of component used.

4.4.5.2 The material for non-pressure parts welded directly to carbon steel pressure parts shall be as follows:

- a. Materials that are essential to the structural integrity or support of an exchanger (such as skirts, saddles, support lugs, trunnions) shall be as specified in Table V, and shall be impact test qualified if not exempted as stated in Note 4 of the notes to Table V.
- b. Materials for attachments that transmit loads to pressure retaining components (such as platform clips, pipe guide clips, ladder clips, etc.) shall be fabricated from materials as indicated in Table V for the applicable MDMT. Impact testing is not required. Structural steel attachments that are not subject to the cold process temperature shall comply with Article 4.5.3.
- c. Material for minor attachments (insulation studs, minor clips, light davits) may be non-impact tested weldable carbon steel.

4.4.5.3 Materials for non-pressure parts that are not directly welded to pressure parts and are not subject to the cold process temperature (such as lower portions of exchanger skirts/saddles, structural pipe supports, etc.) may be non-impact tested carbon steel complying with the applicable code.

4.4.6 Steel Structures and Structural Members

4.4.6.1 Structural members less than ¾ inch (19 mm) thick, and all thicknesses not covered in Paragraph 6.4.2 shall be ASTM A36, ASTM A572 steel, or ASTM A992.

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 14 of 22

4.4.6.2 For structures subject to winter ambient temperatures between -21 °F and -50 °F (-29.4 °C and -45.5 °C), structural members $\frac{3}{4}$ inch (19 mm) thick or thicker shall be made from:

- a. Fine-grain practice, * ASTM A572-S91 steel,
- b. ASTM A573 steel,
- c. ASTM A633 steel or,
- d. ASTM A992, fine grain practice *
- e. Other steels having the impact strength specified in Table IV, tested at the design metal temperature or colder in accordance with ASTM A673 on a heat (H) basis, or Appendix C of AWS D1.1. The welding procedure qualification tests shall include impact tests of the weld metal and the HAZ at the design metal temperature or colder.

TABLE IV
IMPACT STRENGTHS FOR LOW TEMPERATURE STRUCTURAL MEMBERS

STEEL MATERIAL SPECIFICATION	MINIMUM SPECIFIED TENSILE STRENGTH			IMPACT PROPERTIES			
				AVERAGE		MINIMUM	
	KIP/IN ²	KGF/MM ²	MPA	FT- LB	J	FT - LB	J
ASTM A36	ALL	ALL	ALL	13	18	10	14
OTHER STEELS	65 OR LOWER	46 OR LOWER	448 OR LOWER	13	18	10	14
	OVER 65 TO 75	OVER 46 TO 53	OVER 448 TO 517	15	20	12	16
	OVER 75 TO 95	OVER 53 TO 67	OVER 517 TO 655	20	27	15	20

* FABRICATOR SHALL PROVIDE VERIFICATION FROM CURRENT OR PRIOR CERTIFIED MILL TEST REPORTS, THAT ASTM A572 OR A992 WIDE FLANGE SHAPES HAVING THICKNESSES OF $\frac{3}{4}$ INCH (19 MM) OR MORE HAVE BEEN PRODUCED USING A PROCEDURE NECESSARY TO OBTAIN "FINE GRAIN PRACTICE" THAT MEETS THE REQUIREMENTS OF ASTM A6, PARAGRAPH 8.3.

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 15 of 22

TABLE V
SELECTION OF MATERIALS FOR MINIMUM DESIGN TEMPERATURES
(NOTES 1 AND 15)

COMPONENT	MINIMUM DESIGN METAL TEMPERATURE °F (°C) (NOTE 2)						
	-425 TO -321 (-254 TO -196)	-320 TO -156 (-195 TO -104)	-155 TO -56 (-103 TO -49) (NOTE 3)	-55 TO -21 (-48 TO -29)	-20 TO 4 (-28 TO-16)	5 TO 31 (-15 TO -1)	32 TO 59 (0 TO 15)
	ACCEPTABLE MATERIALS PER SPECIFICATION (ASTM UNLESS NOTED OTHERWISE)						
PLATE OR PIPE	A240 TYPES 304, 304L 316, OR 316L (NOTE 13)	A240 TYPES 304, 304L, 316, 316L (NOTE 13) OR A353 OR A553 TYPE I, < 2 IN. (50 MM)	A203 GR D & E < 2 IN.(50 MM) (NOTE 3)	A516 (NOTE 4) (NOTE 5) (NOTE 6)	A516 (NOTE 4) (NOTE 5) (NOTE 6)		
		< 2 IN. (50 MM)	A203 GR A & B < 2 IN.(50 MM) TO -100°F (-73°C) (NOTE 3)				
		A353 TYPE II OR A645 TO -275°F (-170°C)	A537 TO -75°F (-59.4°C) (NOTES 4 & 6)				
TUBE	A249 OR A213 GR TP 304, 304L 316, OR 316L	A249 OR A213 GR TP 304, 304L, 316, OR 316L (NOTE 13) OR A334 GR 8	A179 OR A214 (NOTE 16), OR A334 GR3	A179 OR A214 (NOTE 16), OR A334 G OR GR6	A179, A214, OR A210 GR A-1 (NOTE 4)		
PIPE	A358 OR A312 GR TP 304, 304L 316, OR 316L	A358 OR A312 GR TP 304, 304L 316, OR 316L OR A333 GR 8	A333 GR 3 (NOTE 3)	A53 GR B SMLS OR A106 (NOTE 17), OR A333 GR 1, GR 6, A671 GR CC60 OR A672 GR C60	API 5L OR A53 GR B OR A106 (NOTE 4)	API 5L OR A53 GR A & B OR A106 (NOTE 7)	
WELDING FITTINGS	A403 GR WP304, WP304L, WP316 OR WP316L (SEAMLESS ONLY)		A420 GR WPL3 OR WPL3W	A420 GR WPL6 OR WPL6W	A234 GR WPA OR WPB (NOTE 4)	1/2 IN. (12.5 MM) MAX; A234 GR WPBW OVER 1/2 IN.(12.5 MM) A234 GR WPB (NOTE 4)	
FORGED ASME B16.5 OR B16.47 FLANGES, STD LWN'S, FITTINGS AND VALVES	A182 GR F304 F304L, F316, OR F316L	A182 GR F304, F304L, F316, F316L, OR A522 TYPE II	A350 GR LF3 (NOTE 3) (NOTE 8)	A350 GR LF2 (NOTE 8)	A105 (NOTE 4) (NOTE 8)		
FORGED NONSTANDARD PRESSURE VESSEL AND EQUIPMENT COMPONENTS (NOTE 9)	A336 GR F304, F304L, F316, F316L	A336 GR F304, F304L, F316, F316L OR A522 TYPE II	A765 GR III (NOTE 3) (NOTE 9)	A765 GR I OR GR II (NOTE 9)	A765 GR I OR II A541 A266 IF EXEMPTED FROM IMPACT TESTING BY NOTE 4 & NOTE 9		

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 16 of 22

CAST ASME FITTINGS AND VALVES CAST NON-STANDARD PRESSURE VESSEL COMPONENTS	A351 GRADE TO MATCH WROUGHT CHEMISTRY (NOTE 10)	A743/744 GR CF3 CF8 OR CF8M A352 GR LC4 TO -175 °F (-115 °C) A351 GRADE TO MATCH WROUGHT CHEMISTRY (NOTE 10)	A352 GR LC3 (NOTE 10) A352 GR LC2 TO -100°F (-73 °C)	A352 GR LCB	A216 GR WCA OR WCB (NOTE 14) A336 GR F1 OR A352 GR LCA OR A217
BOLTING	NOTE 11				
STRUCTURAL: STEEL SHAPES AND MEMBERS	9 NI OR 18 CR - 8 NI PROPRIETARY STEEL MATERIALS			ARTICLE 4.5.3 (ALSO SEE NOTE 12)	AISC SPECIFICATIONS
PLATE CLIPS, LUGS, SKIRTS SADDLES, LEGS, ETC.	SAME GENERIC MATERIAL OR CHEMISTRY AS SHELL (SEE PARAGRAPH 4.5.2.2 AND 4.5.2.3) (NOTE 12)				
SHAFT, IMPELLERS, ETC.	SEE API STD 617 OR APPROPRIATE API STANDARD				

NOTES TO TABLE V: (ALL REFERENCES TO DIVISION 1 OR DIVISION 2 REFER TO ASME SECTION VIII)

6. Any material listed for a colder temperature range may be used in a warmer temperature range. For example, A312 Gr TP304 may be used in the temperature range of -55 °F (-48.3 °C) (See Note 2 below) to -21 °F (-29.4 °C) for pipe. Unless otherwise specified, the thicknesses listed in a given temperature range are maximum material thicknesses for that temperature range.
7. The temperature ranges of -21 to -55 °F (-29 to -48 °C), -56 to -155 °F (-49 to -104 °C), and -156 to -320 °F (-104 to -195 °C) are for Section VIII and B31.3 applications. The temperature limits indicated herein may be changed and the impact test requirements of the material or testing specification modified when the applicable code of construction requires methods of impact property verification other than listed in the designated specifications.
8. 3½% Ni forging materials have an intermittent history of having welding problems. If available fabricators do not have successful experience with this material, austenitic stainless steel is a better choice. A333 Gr 3 (3½% Ni) piping materials are not normally available, nor cost effective and not used. For design or normal operating MDMT's colder than -55 °F (-48.3 °C) (see Note 2), and select from the materials listed for temperatures colder than -155 °F (-103 °C).
9. Unless exempted by Division 1, Paragraph UG-20(f) and Paragraph UCS-66, or Division 2, AM-218, this material shall be impact tested at the MDMT or colder and meet the requirements of Division 1, Paragraph UG-84, or Division 2, AM-211 as applicable.
10. Refer to Division 1, UCS-66 or Division 2, AM-218 to determine the desirability of normalizing, and whether impact testing in accordance with the applicable code is required.
11. See also materials designated per curve D in Division 1, Fig. UCS-66 or Division 2, Fig. AM-218.1.
12. Any other material permitted by ASME B31.3 may be used for piping assemblies when the wall thickness is ½ inch (12.5 mm) or less. Pipe that is manufactured from A134, A139, and A211 materials may be used only for air or water service.
13. ASME B16.5, B16.47 Series B, and standard long weld necks (LWN). Ferritic steel flanges conforming to ASME B16.5 and B16.47 and standard Long Weld Necks that have a neck outside

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 17 of 22

diameter not exceeding the hub diameter specified in ASME B16.5 (also called Long Weld Neck flanges) are exempt from impact testing at temperatures not colder than -20 °F (-29 °C). Thick nozzle necks used for integral reinforcement must be evaluated in accordance with UCS-66 and Figure UCS-66.3, or Figure AM-218.2. Figure AM-218.2(g) shows the governing thickness at a vessel shell attachment.

14. Tubesheets, flat covers, and barrel forgings (i.e., "hollow cylinder forgings" including integral types with or without a hub for butt welded attachment) shall conform to SA 765 or SA 266. Other non-standard flanges (such as main body flanges) that exceed ASME B16.5 nominal sizes and having a design pressure/temperature rating greater than Class 300, and ASME B16.47 flanges that exceed Class 300 shall conform to SA 765 or SA 266. When determining impact testing exemptions or requirements, the governing thickness for welded nozzle type forgings is at the weld ends where butt welds are made. The governing thickness for flat heads or tube sheets is the larger of the flat component thickness divided by 4 or the thickness of the pressure part attachment at the welded joint. Refer to ASME Section VIII, Division 1, UCS-66(a) and Figure UCS-66.3, or AM-218.1 and Fig. AM-218.4.
15. Cast austenitic stainless steels for ASME Section VIII, Division 1 and 2 applications shall be impact tested in accordance with the applicable Code. For ASME B31.3 and other applications, such steels shall be tested in accordance with ASME B31.3, Paragraph 323.3.
16. See Table I.
17. The maximum thickness of the part of a structural shape welded directly to a pressure containing component shall be $\frac{3}{4}$ inch (19 mm). When heavier thicknesses are required, or plate or pipe materials are used, the part shall be fabricated from materials conforming to the specification listed in Table V for the type component to which they are welded.
18. Impact test requirements for base materials, PQR's and production test plates as applicable shall be in accordance with the applicable ASME Code.
19. The material is suitable for ASME fittings and valves.
20. ASME specifications have the same numerical designation as the ASTM specifications, but are preceded by SA instead of A (e.g., SA516). ASME specifications shall be in accordance with ASME Section II, Part A.
21. Impact testing is required for thicknesses greater than 0.237 in. (6 mm). Use of A179 and A214 tubing in the temperature ranges shown is limited to Section VIII, Division 1 and 2 applications only. These specifications have a maximum diameter limit of 3 in. (75 mm). Above either of these limits, use impact tested tubing as indicated.
22. For Section VIII, Division 1 and 2 applications only, non impact tested pipe may be used for pressure applications (i.e., nozzle necks) within the following size/thickness limits; up to NPS 4 and not exceeding 0.237 inch (6 mm) thick (Sch 40 for NPS 4). For all B31 applications, and for Section VIII applications exceeding the limit shown, impact testing requirements must comply with the applicable code. (See ASME B31.3, Paragraph 323.2.2, ASME Section VIII, Division 1, UCS-66, and Division 2, AM-218).

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 18 of 22

4.5 Fresh Cooling Water Service

4.5.1 The tube metallurgy for treated and inhibited fresh cooling water service is Killed Carbon Steel.

4.6 Amine Service

4.6.1 When Amine service is specified on the data sheet the requirements of API RP-945 are applicable.

4.7 Hydrogen Sulfide Service

When H₂S or Wet Hydrogen Sulfide service is specified on exchanger datasheet, the requirements of project specification 166000-000-SP-MV09-0004, "Pressure Vessel Requirements for Wet Hydrogen Sulfide (H₂S) Service Specification" shall be met. In addition the following is required:

4.7.1 Addition to 166000-000-SP-MV09-0004 Section 3.1.3 Set-on nozzles are acceptable for Air Cooled heat exchangers.

4.7.2 Deleted.

4.7.3 For Shell and Tube heat exchangers; the tube to tube-sheet joint shall be seal welded.

4.7.4 For Shell and Tube heat exchangers; notch the tie rod spacer tubes on each end and orient the notches vertically during construction to allow the fluid to drain out. After the bundle cage is assembled, cut off the end of the tie rod flush with the nuts, and weld the nuts to the tie rod ends.

4.7.5 Stresses relieve U-bends plus 1 foot straight length on CS or low Cr tubes. Stress relieving via both furnace and induction methods are acceptable per holding temperatures and holding times given in Table UCS-56 of ASME Section VIII Division 1.

4.7.6 High alloy stainless steel tubes shall have the U-bends annealed as follows:

4.7.6.1 The annealing procedure shall consist of heating the material to a minimum temperature of 1900 °F (1040 °C) followed by a rapid cooling to below 700 °F (370 °C). The cooling rate shall be sufficiently rapid to prevent harmful carbide precipitation.

4.7.6.2 The heat treatment shall be applied to the U-bend area plus approximately 12 in. (300 mm) of each leg beyond the tangent point of the U-bend.

4.7.6.3 If the heat treatment is accomplished by resistance-heating methods wherein electrodes are clamped to the tubes, the clamped areas shall be visually examined for arc burns. Burn indications shall be cause for rejection unless they can be removed by local polishing without encroaching upon minimum wall thickness.

4.7.6.4 Temperature control shall be accomplished through the use of optical or emission pyrometers, or both. No temperature-indicating crayons, lacquers, or pellets shall be used.

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 19 of 22

4.7.6.5 The inside of the tube shall be purged with a protective or an inert gas atmosphere during heating and cooling to below 700 °F (370 °C) to prevent scaling of the inside surface. The atmosphere shall be noncarburizing.

4.8 **Hydrogen Service**

4.8.1 When hydrogen service is specified on exchanger datasheet, material shall be selected in accordance with the latest addenda of API 941, "Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants." The material selection shall be based on hydrogen partial pressure adjusted for design pressure,

$[P_{\text{Hydrogen @ Design}} P = P_{\text{Hydrogen @ Operating}} P (P_{\text{Design}} / P_{\text{Operating}})]$ at design temperature.

4.8.2 Gaskets for body flanges shall be Kammprofile or spiral wound flexitallic.

4.8.3 For Hydrogen Service, fabrication using $1\frac{1}{4}\text{Cr}-\frac{1}{2}\text{Mo}$ plate, pipe and forgings where the design temperature is equal to or greater than 825 °F (440 °C), then:

4.8.4 All material shall be limited to 85,000 psi (586.2 MPa) maximum tensile strength and:

- All plate material shall be SA-387-11 Class 1.
- All forged material used for non-standard components shall be SA-336 F11 Class 2.
- All pipe material shall be SA-335 F11.
- All tube material shall be SA-213 T11.
- All forged material used for standard B16.5 or B16.47 flanges shall be SA-182 F11 Class 2 or SA-336 F11 Class 2.
- Other material specifications and classes not listed above are not acceptable.

4.8.4.1 The carbon content of the $1\frac{1}{4}\text{Cr}-\frac{1}{2}\text{Mo}$ material must be equal to or less than 0.13%.

4.8.4.2 $2\frac{1}{4}\text{Cr}-1\text{Mo}$ material may be substituted for $1\frac{1}{4}\text{Cr}-\frac{1}{2}\text{Mo}$ material, only if requested at the time of quotation.

4.8.5 Fabrication using $2\frac{1}{4}\text{Cr}-1\text{Mo}$ plate, pipe, and forgings. If the design temperature is equal to or greater than 850 °F (454 °C) and the component thickness is equal to or greater than 3 inches (75 mm) then full compliance with API RP 934-A, as modified by Appendix A, is mandatory.

5 APPENDICES

5.1 **Addenda to API RP 934-A Requirements**

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 20 of 22

APPENDIX 5.1

ADDENDA TO API RP 934-A REQUIREMENTS

INTRODUCTION

REQUIREMENTS FOR 2¼CR-1 MO MATERIALS AND FABRICATION CORRESPOND TO THOSE OF API RECOMMENDED PRACTICE 934-A WITH THE SPECIFIC OPTIONS, DELETIONS, ADDITIONS OR MODIFICATIONS CONTAINED IN THIS APPENDIX. THE PARAGRAPH NUMBERS IN THIS SPECIFICATION CORRESPOND TO THOSE USED IN API 934-A. PARAGRAPH NUMBERS MAY NOT BE CONSECUTIVE AND ALL API PARAGRAPHS NOT ADDRESSED HEREIN SHALL BE CONSIDERED TO BE MANDATORY. INSTRUCTIONS CONTAINED IN THIS SPECIFICATION SUCH AS "ADD" OR "SUBSTITUTE" SHALL BE INTERPRETED AS FOLLOWS: IF INFORMATION IS "ADDED" TO AN EXISTING PARAGRAPH IN THE API STANDARD, THE REQUIREMENTS OF THIS SPECIFICATION SHALL BE READ AS A CONTINUATION OF THE API PARAGRAPH. IF INFORMATION IS "SUBSTITUTED", THE API REQUIREMENT SHALL BE REPLACED IN ITS ENTIRETY BY THE REQUIREMENTS OF THIS SPECIFICATION. API PARAGRAPHS WHICH ARE "REVISED" HAVE SPECIFIC REVISIONS NOTED IN THIS SPECIFICATION. IF (NEW) IS NEXT TO A PARAGRAPH NUMBER NOT APPEARING IN API 934-A, IT SHALL BE READ AS A CB&I ADDED REQUIREMENT.

1.1 SCOPE (REVISE)

Replace: “ ASME Code Section VIII, Division 2, including Appendix 26” with “ ASME Code Section VIII, Division 1, including Appendix 31 or ASME Code Section VIII, Division 2, including Appendix 26...” This should be paragraph 3.4.3 in the new Div 2.

4 DESIGN

4.1 (Substitute)

Design and manufacture shall conform to ASME Section VIII Division 1 or ASME Section VIII Division 2. The latest edition including addenda effective through the date of the purchase offer shall be used.

4.3.2 Nozzle attachment to shell (substitute)

All nozzle to shell attachment welds shall be UT examined for their full length. The UT procedure shall be in accordance with ASME Section V. The acceptance criteria shall be in accordance with ASME Section VIII, Division 1 Appendix 12 or ASME Section VIII, Division 2 Appendix 9-3.

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 21 of 22

5.4 Heat Treatment

5.4.1 (Add)

The material supplier shall furnish verification for each heat of material that the microstructure consists of a minimum of 90% bainite for the thickness applied. In order to do this, the material supplier may show cooling rates used in steel heat treatment with CCT (critical cooling transformation plots) noting transition from austenite to bainite achieved by sufficient rapid cooling from austenitizing temperatures at mid-thickness of the plate (or forging).

5.5 Mechanical Properties

5.5.2.2 (Substitute)

Elevated temperature tensile test are not required.

5.5.3 Impact Properties

5.5.3.1 (Substitute)

Average impact values at the MDMT or -20 °F (-29 °C) whichever is lower of three Charpy V-notch test specimens heat treated in accordance with 5.5.1.2 shall not be less than 40 ft-lbs (55 joules) with no single value below 35 ft-lbs (47 joules). The percent ductile fracture and lateral expansion in mils shall also be reported.

5.5.3.2 Step Cooling Tests (substitute)

Step cooling testing is not required where the mill supplier is approved and the material chemistry meets the requirements for maximum J-Factor.

7.2 Base Metal Welding

7.2.1.4 (Substitute)

Step cooling testing of the weld metal and HAZ is not required where the supplier of the consumables (and the base materials) are approved and the consumables meet the requirements of a maximum X-Bar-Factor.

7.2.2.2.3 Dehydrogenation Heat Treatment (DHT) (substitute)

An Intermediate Stress Relief in accordance with paragraph 7.2.2.2.2 is required. DHT is not acceptable.

7.2.3.3.2 (Delete)

7.3.2 Disbonding Tests (substitute)

 	HEAT EXCHANGER MATERIALS SPECIFICATION	Document No.: 000-SP-ME07-0006
		Revision: 5
		Date: 10-May-11
		Page: 22 of 22

Weld overlay disbonding test are not required (unless the design criteria exceeds the common disbanding pressure temperature conditions shown within the ASTM G146, Figure 1).

7.4 Final PWHT

7.4.1 (Add)

Local PWHT requires purchaser's acceptance.

11 Documentation (Substitute)

The following documentation for all pressure-retaining parts, including welding consumables, shall be completed and **submitted to the purchaser prior to the start of fabrication.**

- a. CMTR's showing all chemical composition and mechanical test results (tensile, yield, elongation and impact testing).
- b. J-factors.
- c. X-bar-Factors.
- d. Welding procedure specifications (WPS's) and Procedure Qualification Records (PQR's) per ASME IX.
- e. Weld map showing types and location of all welds and configurations with procedure numbers detailed and including proposed NDE.
- f. CCT plots

The following documentation for all pressure retaining parts, including welding consumables, shall be completed prior to the start of fabrication and shall be available for examination by the purchaser at the time of inspection. This documentation shall be submitted to the purchaser at the completion of the project.

- a. All proposed heat treatment data showing hold time and temperature for PWHT and ISR.
- b. Production impact test results.
- c. UT reports for all nozzle to shell welds.