Welded Plate-block Heat Exchangers

API STANDARD 810
FIRST EDITION, 20XX

AMERICAN PETROLEUM INSTITUTE

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Contents

Introduction

Users of this standard should be aware that further or differing requirements may be needed for individual applications. This standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly applicable where there is an innovative or developing technology. Where an alternative is offered, it is the responsibility of the vendor to identify any variations from this standard and provide details.

This standard is intended for the supply and fabrication of new heat exchangers, with requirements provided for design, materials, fabrication, inspection, testing, and through its preparation for shipment. The applicability of this standard to the modification or replacement of existing heat exchangers or heat exchanger components is subject to agreement between the purchaser and the vendor, provided that any applicable jurisdictional and post construction code requirements are met. This standard includes informative annexes which provide the purchaser with guidance when making design choices to be applied to the equipment scope, as well as providing informational guidance on operations and maintenance.

A recommended practice is included within this standard (see Annex A).

This standard requires the purchaser to specify certain details and features.

A bullet [●] at the beginning of a paragraph or subsection indicates a requirement for the purchaser to make a decision or provide information (for information, a checklist is provided in Annex B).

In this standard, where practical, U.S. customary units are included in parentheses for information.

Welded Plate-block Heat Exchangers

1 Scope

This standard gives requirements and recommendations for the mechanical design, materials selection, fabrication, inspection, testing, and preparation for shipment of welded plate-block heat exchangers for use in petroleum, petrochemical and natural gas industries. It is applicable to heat exchangers with welded plate cores and bolted cover plates.

This standard excludes heat exchangers with welded plate-block(s) within a cylindrical shell, or those where all process sides are not accessible for mechanical cleaning by removable panels. Also excluded are plate and frame heat exchangers, including semi and fully welded plate and frames, which are covered in API Standard 667.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Recommended Practice 941, *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants*

ASME B16.25 [1], *Buttwelding Ends*

ASME PCC-1, *Guidelines for Pressure Boundary Bolted Flange Joint Assembly*

NACE MR0103 [2], *Petroleum, Petrochemical and Natural Gas Industries—Metallic Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*

NACE MR0175, *Petroleum and Natural Gas Industries—Materials for Use in H_2S-containing Environments in Oil and Gas Production—Parts 1, 2 and 3*

NACE SP0472, *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*

1 ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org

2 NACE International (formerly the National Association of Corrosion Engineers), now AMPP, The Association for Materials Protection and Performance, 15835 Park Ten Place, Houston, Texas 77084, www.nace.org.

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1
baffle
pass partition plate
Plate or similar component used in multi-pass arrangements to direct the fluid flow between adjacent passes within the plate pack..

3.2
baffle cage
Rectangular frame that is fitted between the column liners and head liners. This frame holds the baffles in place.

3.3
channel
Fluid flow passage between adjacent plates.

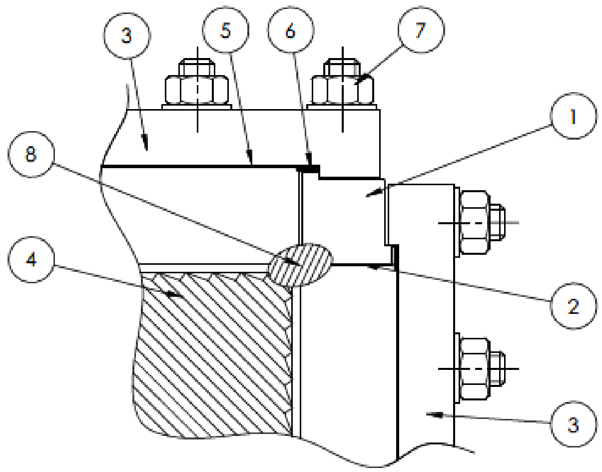
3.4
flow channel width
Nominal plate size in the direction perpendicular to flow.

3.5
column
Structural and pressure-retaining element located at the corners of the plate pack to anchor the panels and fixed heads.

3.6
column liner
Metallic angled plate that is welded to the corners of the plate pack for the attachment of the plate pack to the columns, isolation of the columns from the process fluid and prevents fluid intermixing.

NOTE 1 The column liners and head liners together provide a continuous gasket seating face for the panel gasket.

NOTE 2 Figure 1 shows a typical configuration of the column liner within the adjacent parts of a welded plate-block heat exchanger.



Key:
1 Column
2 Column liner
3 Panel
4 Heat transfer plate
5 Panel liner
6 Panel gasket
7 Panel bolting
8 Method of attachment proprietary to manufacturers

Figure 1 — Typical Plate Pack and Panel Assembly Details

3.7
cyclic service
Process operation with periodic variation in temperature, pressure, and/or flow rate.

3.8
fixed head
Structural component, not wetted by nor providing access to the process fluids, which also provides pressure-retaining reinforcement to the plate pack..

3.9
header
External half pipe or box used to uniformly distribute the fluid to the plate pack.

3.10
head liner
Metallic flat plate with flanged edges that is welded to the plate pack and column liners to isolate the fixed heads from the process fluid.

NOTE The flanged edges of the column liners and head liners together provide a continuous gasket seating face for the panel gasket.

3.11
head sheet
Non-metallic sheet that may be used between the head liner and the fixed head.

3.12
heat exchanger unit
One or more welded plate-block heat exchangers arranged in series or parallel for a specified service that operate together to perform the intended duty.

3.13
heat transfer area
Sum of the surface areas of one side of all the heat transfer plates in contact with both heat-transfer fluids.

NOTE Areas of end plates are not included.

3.14
heat transfer plate
Pressure vessel quality metal plate that is precision-pressed or formed into a pattern(s).

3.15
high temperature hydrogen attack
HTHA
Damage mechanism affecting carbon and low-alloy steels due to the exposure to hydrogen at elevated temperatures and pressures, resulting in the loss of carbides and strength of the materials and cracking.

3.16
high temperature hydrogen service
HTHS
Services with operating hydrogen partial pressure above 350 kPa (50 psi) absolute and operating temperatures above 200 °C (400 °F).

3.17
hydrogen service
Process streams containing hydrogen with an absolute partial pressure greater than 350 kPa (50 psi).

3.18
item number
Purchaser's identification number for a heat exchanger.

3.19
minimum design metal temperature
MDMT
Lowest metal temperature at which pressure-retaining components can be subjected to design pressure.

EXAMPLE Ambient temperature or minimum process fluid temperature.

3.20
nozzle liner
connection liner
Thin alloy sleeve on nozzle components to isolate the process fluid from the pressure boundary backing material.

3.21
panel
cover plate
Provides pressure containment and access to the plate pack.

3.22
panel gasket
Gasket used to provide a seal between the panel and the column liner and head liner.

3.23
panel liner
Corrosion resistant material that may be used to isolate the panel from the fluids.

3.24
welded plate-block heat exchanger
Assembly of a welded plate pack and its panels, fixed heads and columns.

NOTE Figure 2 shows typical components of a welded plate-block heat exchanger.

3.25
plate chevron angle
Angle formed between the plate pattern and the line perpendicular to the flow direction for corrugated plate patterns.

NOTE Figure 3 shows the angle related to the flows.

3.26
plate gap
$2b$
Maximum distance between adjacent corrugated or pressed heat transfer plates.

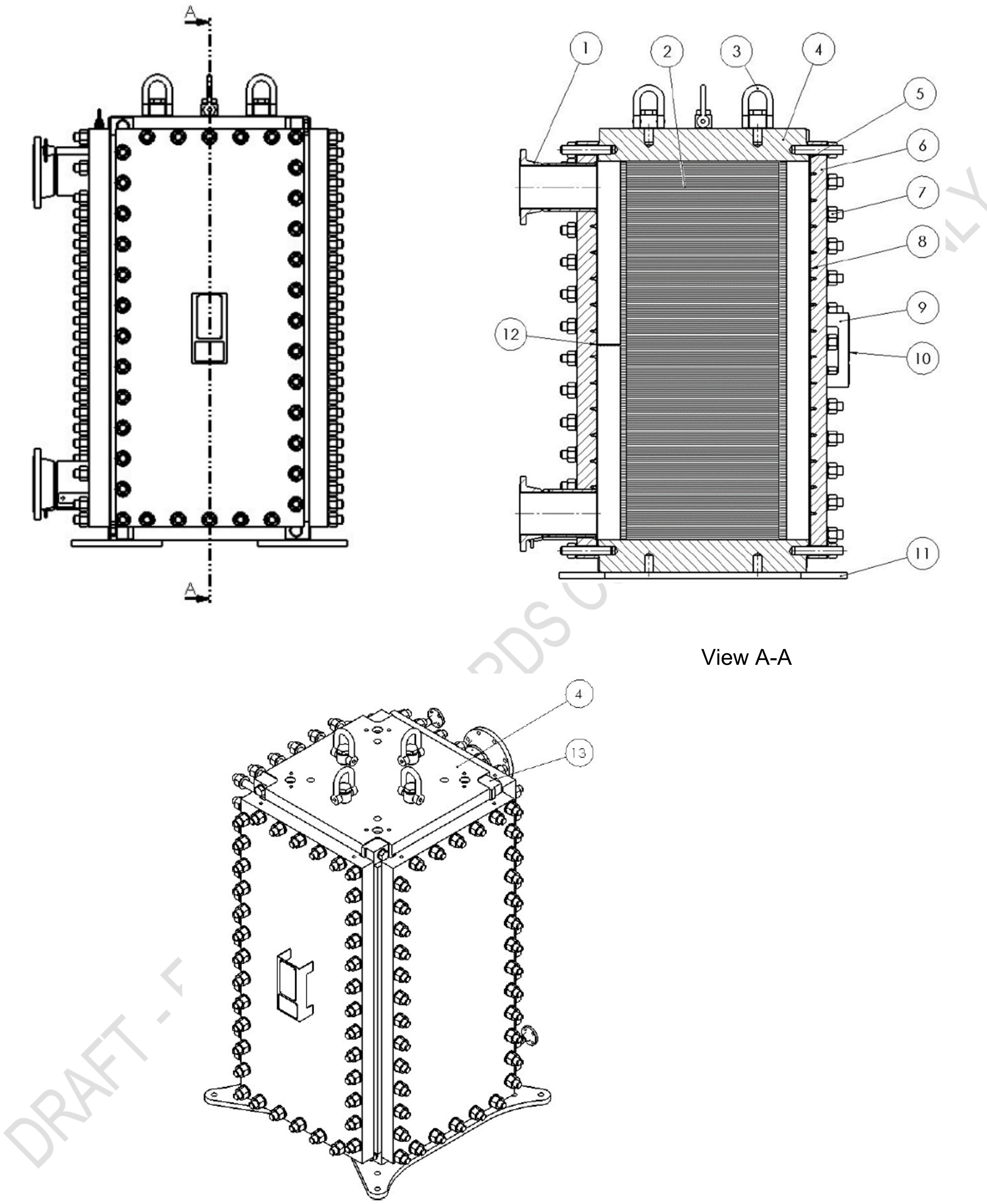
NOTE Figure 4 shows typical plate gaps.

3.27
plate pack
Welded assembly of heat transfer plates, including column liner and head liner.

3.28
pressure design code
Recognized pressure vessel design code or standard as specified or agreed by the purchaser.

EXAMPLE ASME *BPVC Section VIII, Division 1*, EN 13445 (all parts).

3.29
structural welding code
Recognized structural welding code as specified or agreed by the purchaser.

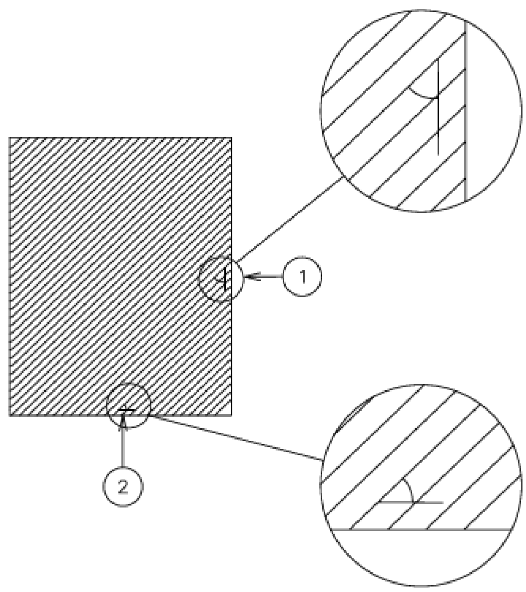


Key

1	Nozzle	8	Panel liner
2	Plate pack	9	Nameplate bracket
3	Lifting devices	10	Manufacturer’s nameplate
4	Fixed head	11	Support

5 Panel gasket
6 Panel or cover plate
7 Bolting
12 Baffle or Pass Partition Plate
13 Column

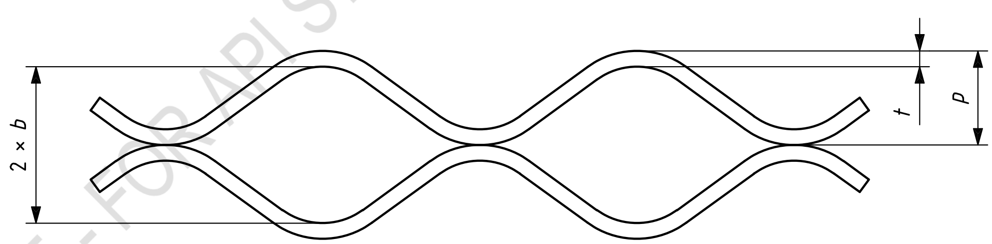
Figure 2—Typical Welded Plate-block Heat Exchanger



Key

1 Stream 1 – plate chevron angle
2 Stream 2 – plate chevron angle

Figure 3—Plate Chevron Angle



Where $b = p - t$

Key

$2 \times b$ plate gap
b forming or pressing depth
t plate thickness
p compressed pitch per plate

Figure 4—Plate Gap

4 General

- **4.1** The pressure design code shall be specified or agreed by the purchaser. Pressure components (e.g. panels, fixed heads, columns, bolting, and nozzles) shall comply with the pressure design code and the supplemental requirements in this standard.

- **4.2** The structural welding code shall be specified or agreed by the purchaser.

4.3 Annex A includes recommended mechanical and design details for information.

4.4 Annex B provides a checklist that can be used by the purchaser to ensure that bulleted items in this standard are addressed.

4.5 Annex C provides examples of datasheets.

- **4.6** The vendor shall comply with the applicable local regulations specified by the purchaser.

- **4.7** The purchaser shall specify if the hot or cold fluid is designated as sour in accordance with NACE MR0175 (all parts) for oil and gas production facilities and natural gas processing plants or is designated as wet hydrogen sulfide service in accordance with NACE MR0103 for other applications (e.g. petroleum refineries, LNG plants, and chemical plants), in which case all carbon steel materials and welds in contact with the process fluid shall meet the requirements of the applicable standard to mitigate potential for sulfide stress cracking (SSC). Identification of the complete set of materials, qualification, fabrication, and testing specifications to prevent in-service environmental cracking is the responsibility of the user (purchaser). See A.2.1 for guidance on sour or wet hydrogen sulfide service.

- **4.8** The purchaser shall specify if the hot and/or cold side is in hydrogen service.

- **4.9** The purchaser shall specify if the requirements of 4.7, 8.2, and the related clauses for sour or wet hydrogen sulfide service, shall be applied where carbon steel is isolated from process fluid contact by the use of liners. See A.2.1.5 and A.4.4.4 for additional guidance on the use of loose liners.

- **4.10** The purchaser shall specify if cyclic service design is required. See A.2.2 for additional guidance on cyclic service.

4.11 If cyclic service is specified, the purchaser shall specify the type and magnitude of variation in pressure, temperature, different modes of operation and flow rate, the time for the variation (hours, weeks, months, etc.) and the number of cycles or frequency for this variation expected during the life of the equipment. The extent and acceptance criteria of any required analysis shall be subject to the agreement of the purchaser.

4.12 For design guidance on minimum operating pressure differentials between streams and off-design conditions such as start-up, shut-down and transient operations, see A.2.3.

4.13 For guidance on failure scenarios and troubleshooting see A.2.4.

- **4.14** The purchaser shall specify which streams are to be accessible for mechanical cleaning. See 7.5.1.2.

5 Proposal Information Required

5.1 The vendor's proposal shall include, as a minimum, the following information:

a) datasheet;

b) preliminary general arrangement drawing including overall dimensional information and weight;

c) nozzle sizes and locations;

d) gasket material and type, for both the panels and baffles;

e) plate material, thickness, plate corrugation type, and dimensions;

f) number of plates;

g) description of the proposed method for baffle sealing;

h) description of the proposed method for attaching the column liner and head liner to the plate pack;

i) details of the attachment of the panel liner to the panel;

j) details of connections including any lining, cladding and method of attachment to panels;

k) recommended spare parts list.

5.2 For components that are not fully identified in Section 3, the vendor shall describe the details of construction and assembly.

5.3 The proposal shall include a detailed description of all exceptions to the requirements of the purchaser's inquiry.

5.4 The first-time use of a new technology, design, component, or material shall be clearly indicated by the vendor. See A.3 for additional guidance.

5.5 The vendor shall specify in the proposal the operating limitations (e.g. pressure and temperature limits, flow conditions, variations/frequencies/rates of change in flow rate, pressure, and temperature) for normal operating and startup/shutdown/warm-up/cool-down cases.

6 Drawings and Other Data Requirements

6.1 Outline Drawings and Other Supporting Data

The vendor shall submit, for review by the purchaser, outline drawings for each welded plate-block heat exchanger unit. The drawings shall include at least the following information:

a) service, item number, project name and location, purchaser’s order number, vendor’s shop order number and other special identification numbers;

b) design pressure, test pressure, maximum design temperature, minimum design metal temperature and any restrictions on testing or operation of the heat exchanger;

c) connection sizes, location, orientation, projection, direction of flow and, if flanged, the rating and facing including any lining, cladding and method of attachment to the panels;

d) dimensions and location of supports, including bolt holes and slots;

e) overall dimensions of the heat exchanger;

f) mass of the heat exchanger, empty and full of water;

g) specified corrosion allowance for each side of the heat exchanger;

h) clearances required for panel removal;

i) references to the applicable code and the purchaser's specification(s);

j) requirements for NDE examination;

k) requirements for surface preparation and painting;

l) gasket materials and type;

m) location of nameplates, lifting devices, grounding clips and other attachments;

n) location of center of gravity of the exchanger (empty and full of water);

o) material specifications including grades for all components;

p) forces and moments on connections;

q) recommended torque values for panel bolting.

6.2 Information Required After Outline Drawings Are Reviewed

6.2.1 The vendor shall submit gasket details on a separate document, including type, material, dimensional details, and location of interlocks between sections for multiple piece gaskets, if applicable. This drawing shall not be marked with any restrictions for use.

6.2.2 Upon receipt of the purchaser's review comments on the outline drawings, the vendor shall submit copies of all detailed (nonproprietary) drawings and relevant documentation for the purchaser's review. These shall fully describe the heat exchanger and shall include at least the following information:

a) full views with dimensions, unit orientation and materials;

b) plate pack, including plate size, number of plates, passes, column liner and head liner attachment details;

c) heat transfer plate description, including plate type, plate thickness, chevron angle if applicable and plate gap;

d) baffle cage assembly drawing;

e) details of each weld for nonpressure attachments welded to pressure parts (including attachment of liners), for all load bearing attachments, and pressure-retaining welds, including weld material, weld nominal thickness, weld location and applicable nondestructive examination methods;

f) details of the welds joining heat transfer plates, including weld location and applicable nondestructive examination;

g) complete bills of materials, including the material specifications and part numbers for all proprietary components;

h) details of cladding and weld overlay;

i) flange-face finish;

j) clearance required for opening of any swing or hinged panels;

k) lifting devices.

● **6.2.3** If specified by the purchaser, the vendor shall furnish copies of applicable welding procedure specifications, welding procedure qualifications, and weld map for review or record.

● **6.2.4** If specified by the purchaser, the vendor shall furnish copies of applicable calculations for review or record, including mechanical design calculations for supports, lifting devices and nozzle load calculations.

● **6.2.5** If specified by the purchaser, the vendor shall furnish copies of applicable detailed inspection and test plans, and associated NDE procedures for review or record.

● **6.2.6** If specified by the purchaser, the vendor shall furnish copies of applicable interstream and external testing procedures for review or record.

6.3 Reports and Records

● After the heat exchanger is completed, the vendor shall furnish the purchaser with the following documents in the format and quantities specified by the purchaser:

a) “as-built” datasheet;

b) all outline and nonproprietary detail drawings, marked “CERTIFIED AS-BUILT”;

c) all mechanical design calculations, marked "CERTIFIED AS-BUILT";

d) certified material test reports (CMTR) for heat transfer plates, all pressure-retaining parts, and nonpressure-retaining liners. Each material test report shall be identified by a part number;

e) completed manufacturer’s data report in accordance with the pressure design code;

f) nameplate rubbing or a photograph;

g) all associated NDE reports, including radiographic, magnetic-particle, liquid-penetrant, ultrasonic, hardness, impact, positive material identification (PMI) and any other reports as applicable;

h) pressure test records or report;

i) spare parts list;

j) user's manual containing:

   1) technical description;

   2) operating instructions;

   3) installation and maintenance instructions (including lifting, handling, panel assembly and disassembly, field pressure testing, and leak testing procedures), along with a list of any special tooling that is required.

7 Design

7.1 Design Temperature

● **7.1.1** The purchaser shall specify a maximum design temperature and a minimum design metal temperature.

7.1.2 The design temperature of a component (including external bolting) influenced by both the hot side and cold side fluids shall be the more severe of either the hot side or cold side design temperature.

7.2 Design Pressure

Unless otherwise specified or approved by the purchaser, the heat exchanger shall be designed for design pressure on either side, with atmospheric pressure or if specified vacuum on the other side.

7.3 Fouling Margin

● The purchaser shall specify a percentage fouling margin, F, calculated by

$$F = \left(\frac{U_{\text{clean}}}{U_{\text{service}}} - 1 \right) \times 100 \qquad (1)$$

where U is the heat transfer coefficient (overall thermal transmittance).

See A.4.1 for additional guidance on fouling margins.

7.4 Corrosion Allowance

● **7.4.1** The purchaser shall specify the corrosion allowance to be applied to the wetted surfaces of all components if they are not otherwise provided in corrosion resistant materials, or with corrosion resistant linings or weld overlay.

7.4.2 Corrosion allowance shall not be added to heat transfer plate thickness. See A.4.2 for additional information on corrosion allowance.

7.5 Components

7.5.1 Plate Pack

7.5.1.1 The nominal thickness of the heat transfer plates before being pressed shall not be less than 0.8 mm (0.031 in.).

7.5.1.2 When mechanical cleaning is specified the plate pattern shall facilitate the cleaning by mechanical means, e.g. hydroblasting. See A.4.3 for guidance on chemical and mechanical cleaning.

7.5.1.3 All plate pack welds shall be accessible for inspection and repair.

7.5.2 Fixed Heads

7.5.2.1 Fixed heads shall be bolted to the panels with bolts of the same material as the panel to column bolts.

7.5.2.2 A head sheet may be used between the fixed head and the head liner to provide isolation.

7.5.3 Panels

7.5.3.1 Panel design shall include the effects of pressure load, nozzle loads, and the load imposed by the bolting.

7.5.3.2 Stiffeners shall not be used as a means of retaining pressure, unless otherwise approved by the purchaser.

7.5.3.3 Jackscrews or a minimum clearance of 5 mm (3/16 in.) shall be provided at the panel periphery to facilitate dismantling.

7.5.3.4 Minimum bolt and stud diameter shall be 19 mm (¾ in.).

7.5.3.5 The minimum spacing between bolt centers shall allow nut removal with the use of standard sockets and wrenches, or hydraulic tensioning equipment when applicable.

7.5.3.6 Washers shall be provided except in cases where hydraulic tensioners are to be used. Washers shall conform to the requirements of ASME PCC-1 and be suitable for reuse unless otherwise specified by the purchaser.

7.5.3.7 The spacing between bolts straddling corners shall be such that the diagonal distance between them shall not exceed the lesser of the spacing on the sides or the ends.

7.5.4 Baffles

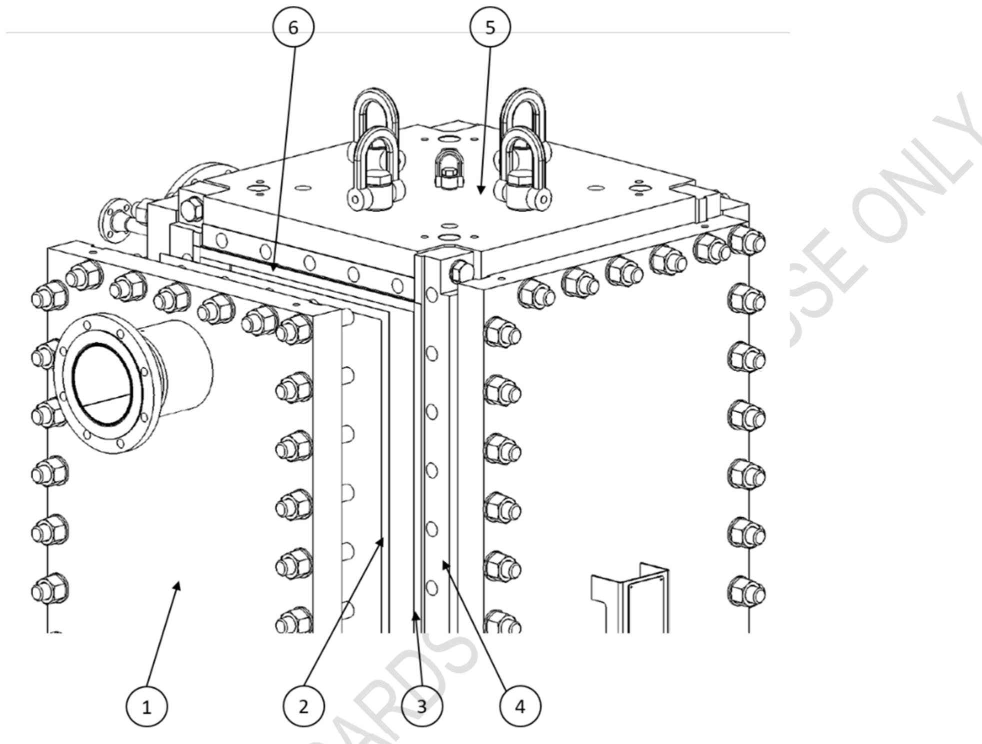
7.5.4.1 Baffles shall be integrally attached to the baffle cage and designed to seal against the panel and plate pack.

7.5.4.2 Each baffle shall be designed for at least twice the total clean allowable pressure drop across the exchanger.

7.5.4.3 Baffles may be provided with reinforcement / tie rods affixed to the baffle cage.

7.5.5 Columns

Each column and fixed head shall interlock both with the fixed head and the adjacent panels. See Figure 5.



Key

1	Panel	4	Column
2	Panel gasket	5	Fixed head
3	Column liner	6	Fixed head liner

Figure 5 — Typical Construction of Column Configuration and Attachment to Fixed Head and Removable Panels

7.5.6 Column Liners

7.5.6.1 The minimum column liner thickness shall be 1 mm (0.04 in.) or the heat transfer plate thickness, whichever is greater.

7.5.6.2 The column liner gasket contact width shall not be less than 9 mm (3/8 in.).

7.5.7 Panel Liners

7.5.7.1 The minimum panel liner thickness shall be 1 mm (0.04 in.) or the heat transfer plate thickness, whichever is greater.

7.5.7.2 Panel liners shall extend to the outer periphery of the panel gasket as a minimum.

7.5.7.3 Panel liners shall be attached to the panel by plug welding either directly to the panel, or to recessed alloy inserts which are threaded into the panel.

● **7.5.7.4** When specified by the purchaser, panels shall be weld overlay, integrally-clad, or explosion-welded. See A.4.4 for guidance on weld overlay and integral cladding.

7.5.8 Nozzle Liners

7.5.8.1 The minimum nozzle liner thickness shall be 1.0 mm (0.04 in.) or the heat transfer plate thickness, whichever is greater.

7.5.8.2 Nozzle liners shall completely cover the gasketed area of the nozzle flange, and shall be fillet welded to the panel liner.

7.5.8.3 The liner may be fabricated by welding, machining, or by forming.

● **7.5.8.4** When specified by the purchaser, nozzles shall be weld overlay or integrally-clad. See A.4.4 for guidance on weld overlay and integral cladding.

7.5.9 Grounding Clips

A grounding clip shall be attached to at least one of the panels or a fixed head.

7.6 Nozzles and Other Connections

7.6.1 Connections shall be flanged and welded to the panel. Studded connections may be permitted if agreed upon by the purchaser.

NOTE Typical connection geometries are shown in Figure 6. The examples shown are not to be construed as preferred types.

● **7.6.2** The use of studded and/or flanged connections shall be specified by the purchaser and included on the datasheet. The purchaser shall specify the required flange design code, e.g. ASME B16.5.

7.6.3 For nozzles welded to panels, set-in connections shall be used unless otherwise specified by the purchaser or when prohibited by clause 7.6.5. See A.4.6 for additional information on set-on versus set-in nozzles.

7.6.4 Flanged connections shall be of one of the following types:

a) forged integrally flanged;

b) pipe or forged cylinder welded to forged welding-neck flange;

c) pipe welded to a forged slip-on flange if agreed by the purchaser, except where excluded by 7.6.5.

7.6.5 Slip-on flanges or set-in connections attached with fillet or partial penetration welds shall not be used in any of the following conditions:

a) for design pressure greater than 2100 kPa (ga) (300 psig);

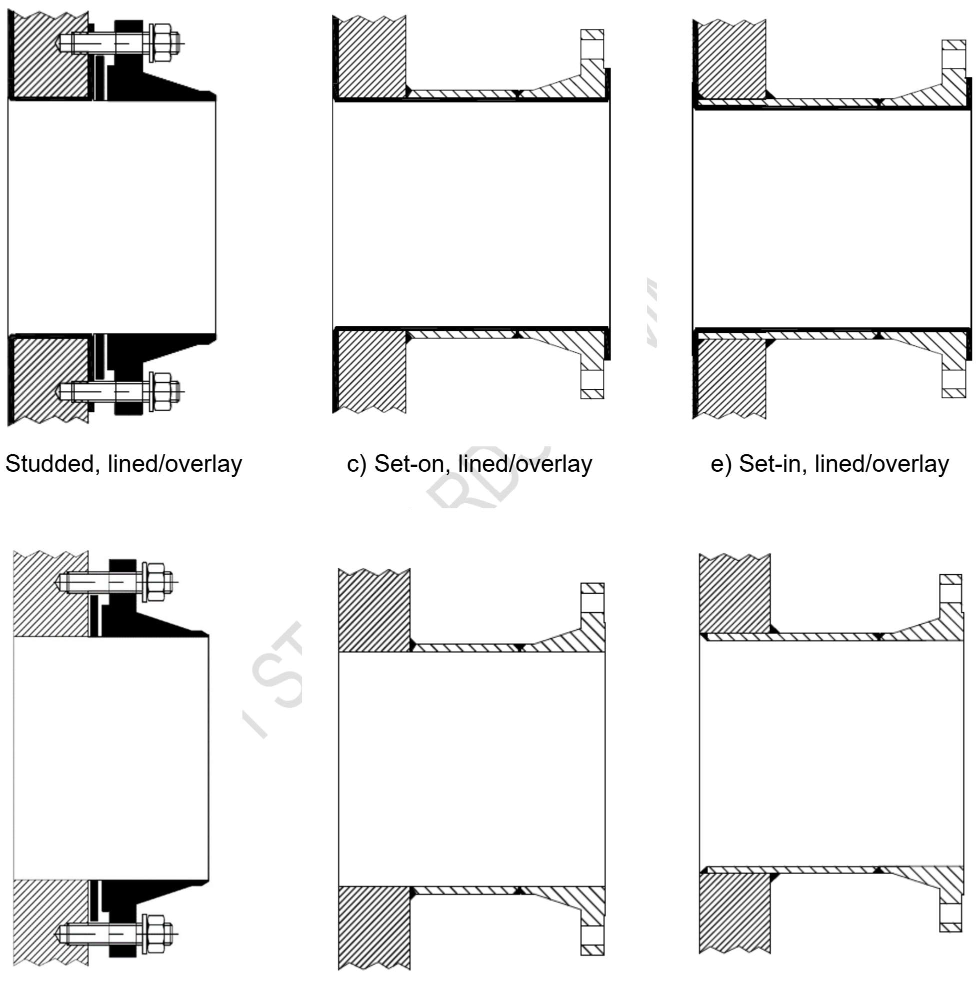
b) for design temperature greater than 400 °C (750 °F);

c) for corrosion allowance greater than 3 mm (1/8 in.);

d) in hydrogen, sour or wet hydrogen sulfide service;

e) in cyclic service;

f) when PWHT is required.



a) Studded, lined/overlay c) Set-on, lined/overlay e) Set-in, lined/overlay

b) Studded, unlined d) Set-on, unlined f) Set-in, unlined

NOTE Mating flanges, gaskets, nuts and washers shown in a) and b) are by others.

Figure 6 — Typical Connection Geometries

7.6.6 The heat exchanger shall be capable of self-draining and self-venting through either the process connections or dedicated drain and vent connections.

- **7.6.7** When insulation is specified by the purchaser the projection of flanged connections shall allow through-bolting to be removed from either side of the flange without removing the insulation. The insulation thickness shall be specified by the purchaser.

- **7.6.8** The size, type, and location of chemical cleaning connections, if any, shall be specified by the purchaser.

7.6.9 All bolt holes for connections shall straddle centerlines.

7.6.10 Connection sizes of DN 32 (NPS 1 1/4), DN 65 (NPS 2 1/2), DN 90 (NPS 3 1/2) or DN 125 (NPS 5) shall not be used.

7.6.11 When butt-welded connections to the piping are to be used, the purchaser shall specify the corresponding piping wall thickness. The wall thickness at the prepared end shall be equal to that of the connecting piping. The weld ends shall be beveled by others in accordance with ASME B16.25.

7.6.12 Lined connections shall not be used in cyclic services which require a fatigue analysis.

7.6.13 The use of solid alloy nozzles in lieu of lined connections is subject to the approval of the purchaser.

- **7.6.14** When specified by the purchaser, a threaded tell-tale hole shall be provided on the bottom of the nozzle necks. See A.4.5 for additional guidance on tell-tale holes.

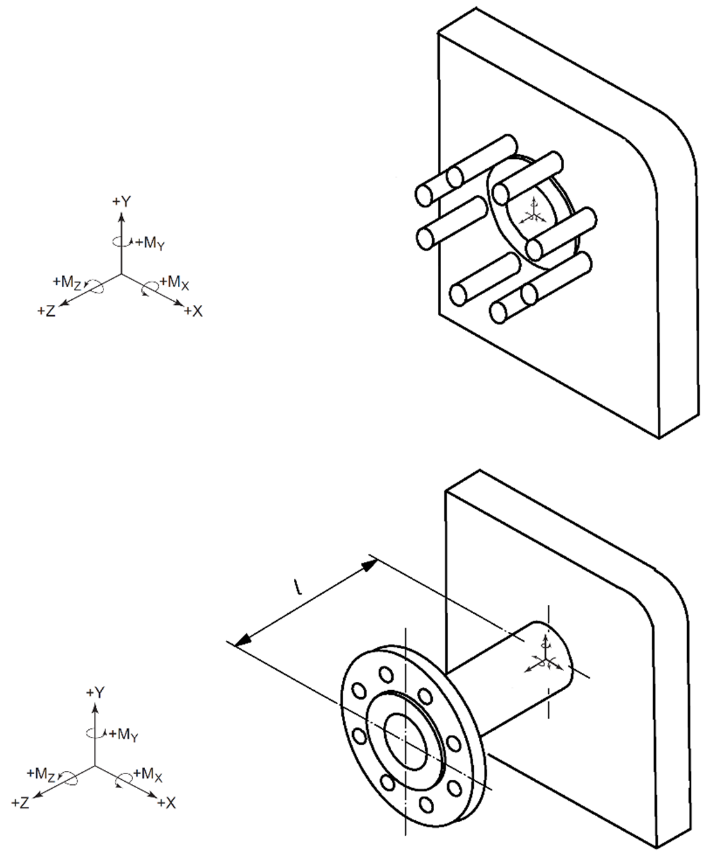
7.6.15 Each nozzle, in its corroded condition, shall be designed to withstand the simultaneous application of the forces (F) and moments (M) applied at the nozzle neck to cover plate interface, as shown in Figure 7 and listed in Table 1, unless otherwise specified by the purchaser. The axial nozzle load shall be considered in both directions (+, -) in conjunction with other nozzle loads. These moments and forces shall be the total from all sources, including dead loads and thermal loads. Non-piped auxiliary connections, such as vents and drains, are excluded from this requirement. The type of analysis applied shall be specified or agreed with the purchaser. See A.4.7 for additional guidance on nozzle loadings.

7.6.16 The nozzle flange design shall be evaluated with consideration of the externally applied piping loads. If the pressure vessel code does not provide a method to evaluate the impact of the externally applied piping loads on a nozzle flange design, the method of analysis shall be agreed upon between the vendor and the purchaser.

7.6.17 Drilled and tapped holes for studded connection bolts shall provide a minimum thread engagement of 1.25 times the stud diameter. The threaded holes shall not pass completely through the panel.

7.6.18 When headers are used, the design and manufacturing details shall be agreed with the purchaser. Each header and header attachment to the panel shall be designed to withstand the simultaneous applications of the piping resultant moments and forces, unless otherwise specified by the purchaser.

7.6.19 Nozzles and couplings shall not protrude beyond the inside surface of the component to which they are attached.



Key

F force

l length of connection

M moment

Figure 7—Directions of Forces on Connections

Table 1— Nozzle Allowable Forces and Moments at the Nozzle to Panel Intersections

Nom. Size		PN 20 (ASME rating 150)				PN 50 (ASME rating 300)				PN 110 (ASME rating 600)			
		F		*M*		*F*		*M*		*F*		*M*	
DN	(NPS)	N	(lbf)	N·m	(lbf·ft)	N	(lbf)	N·m	(lbf·ft)	N	(lbf)	N·m	(lbf·ft)
≤ 50	≤ (2)	416	(93)	151	(111)	547	(123)	161	(118)	809	(182)	179	(132)
80	(3)	730	(164)	459	(339)	961	(216)	492	(363)	1,422	(320)	558	(412)
100	(4)	955	(215)	715	(527)	1,256	(282)	775	(572)	1,859	(418)	896	(661)

150	(6)	1,553	(349)	1,500	(1,106)	2,043	(459)	1,680	(1,239)	3,024	(680)	2,040	(1,505)
200	(8)	2,193	(493)	2,471	(1,823)	2,885	(649)	2,863	(2,111)	4,270	(960)	3,646	(2,689)
250	(10)	2,866	(644)	3,619	(2,669)	3,771	(848)	4,334	(3,197)	5,582	(1,255)	5,766	(4,252)
300	(12)	3,567	(802)	4,941	(3,645)	4,694	(1,055)	6,112	(4,508)	6,947	(1,562)	8,453	(6,235)
350	(14)	4,292	(965)	6,441	(4,750)	5,647	(1,270)	8,216	(6,060)	8,358	(1,879)	11,776	(8,678)
400	(16)	5,038	(1,133)	8,120	(5,989)	6,629	(1,490)	10,666	(7,867)	9,811	(2,206)	15,757	(11,622)
450	(18)	5,803	(1,305)	9,986	(7,365)	7,635	(1,716)	13,485	(9,946)	11,300	(2,540)	20,482	(15,106)
500	(20)	6,585	(1,480)	12,043	(8,882)	8,664	(1,948)	16,693	(12,312)	12,823	(2,883)	25,992	(19,171)

NOTE The data above are based on the following equations:

$$F = \frac{7.5 \cdot \mathrm{DN}^{1.2} + 0.1 \cdot \mathrm{PN} \cdot \mathrm{DN}^{1.2}}{2.5}$$

$$M = \frac{4(\mathrm{DN} - 25)^{1.4} + (2 \times 10^{-5})\,\mathrm{PN} \cdot \mathrm{DN}^{2.7}}{2.5}$$

where $F = F_x = F_y = F_z$; $M = M_x = M_y = M_z$

7.7 Gaskets

7.7.1 Panel Gaskets

7.7.1.1 Panel gaskets shall be confined on the outer perimeter. See A.4.8 for additional guidance on panel gaskets.

● **7.7.1.2** When specified by the purchaser the gasket shall be confined on both the outer and inner perimeters.

7.7.1.3 When multiple piece gaskets are used, interlocks shall be provided between gasket sections.

7.7.1.4 Grooved metal gaskets with graphite facings shall be as follows:

a) The top of the serrations at the weld shall be flat in comparison with the rest of the gasket. The grooves shall be dressed to match the standard profile.

b) Thickness variations in the metallic gasket core, after completion of gasket fabrication, shall not exceed 0.13 mm (0.005 in.).

7.7.2 Baffle Sealing

Baffles shall be designed to minimize bypass of the fluid, by use of a flexible seal, interlock system, or equivalent configuration.

7.8 Lifting Devices

7.8.1 Lifting devices designed to lift the complete heat exchanger shall be:

a) attached to the fixed head(s) with a:

  1) minimum of one lifting device for vertically installed exchangers;

  2) minimum of two lifting devices for horizontally installed exchangers.

b) I-bolts or swivel shackles with holes not less than 32 mm (1 1/4 in.) in diameter;

c) designed to support at least twice the mass of the entire exchanger and consider shipping, erection and maintenance positions;

d) located above the center of gravity;

e) designed to allow for the exchanger to be reoriented from its installed position when required for maintenance;

f) unless otherwise specified by the purchaser, lifting devices shall be either bolted or welded.

7.8.2 Lifting devices designed to lift individual components, e.g. panels, shall:

a) not be used to lift the entire exchanger;

b) be designed to support at least twice the mass of the component being lifted;

c) allow disassembly of all panels in the installed position;

d) allow disassembly of all panels in any orientation required for maintenance;

e) be provided with a hole(s) not less than 32 mm (1 1/4 in.) in diameter.

7.8.3 Insulation supports shall be designed to prevent water collection.

8 Materials

8.1 General

8.1.1 Castings shall not be used, unless approved by the purchaser.

8.1.2 Material for external parts that are welded directly to the pressure parts (such as lifting devices, nameplate brackets, clips and supports) shall be of the same nominal composition as the material to which they are welded, except for grounding clips.

● **8.1.3** The purchaser shall specify the materials for all components in contact with the process fluid.

8.1.4 If cladding (including weld overlay) is used, the full cladding thickness including weld overlay restoration shall be considered as corrosion allowance, and not considered as part of the pressure-retaining envelope, unless otherwise specified or approved by the purchaser. See A.4.4 for guidance on weld overlay and integral cladding.

8.1.5 Weld overlays (including weld overlay restoration) shall have sufficient thickness to provide the specified chemical composition to a depth of at least 1.5 mm (1/16 in.) from the finished surface unless otherwise specified by the purchaser.

8.1.6 Panel gaskets shall be from the following materials:

a) graphite;

b) graphite with metal reinforcement;

c) grooved metal with graphite facing;

d) PTFE;

e) Reinforced PTFE;

f) non-aramid fiber.

8.1.7 Baffle cages and baffles shall be the same material as the plate pack.

8.1.8 Column liners and head liners shall be the same material as the plate pack.

8.1.9 Panel liners and nozzle liners, when provided, shall be the same material as the plate pack, unless otherwise specified by the purchaser.

8.1.10 Allowable stresses that have been established on the basis of short-time tensile strength shall not be used for the design of gasketed panels.

NOTE In ASME *BPVC, Section II*, the allowable stresses of some materials have been established in this way. These stress values may result in dimensional changes due to permanent strain and shall not be used for flanges for gasketed joints where slight distortion can cause leakage.

8.2 Requirements for Materials in Sour or Wet Hydrogen Sulfide Service

8.2.1 Materials shall be supplied in accordance with NACE MR0175 (all parts) or NACE MR0103, as applicable.

8.2.2 Carbon steel materials shall be supplied in the normalized condition, unless otherwise approved by the purchaser. The acceptability of hot-formed material shall be subject to approval of the purchaser.

● **8.2.3** The purchaser shall specify any other restrictions on the supply of materials including the need for chemistry controls and residual elements, base metal hardness requirements, hydrogen induced cracking (HIC) testing requirements, etc.

9 Fabrication

9.1 Welding

9.1.1 All pressure-retaining welding shall be in accordance with the pressure design code. Structural welding shall be in accordance with the structural welding code, unless otherwise specified by the purchaser. See A.5 for additional guidance on welding.

9.1.2 Welds attaching set-on connections to cover plates shall be full penetration.

9.1.3 Welds may be made using any welding process other than oxyacetylene gas welding.

9.1.4 Welds for load bearing external attachments (such as lifting devices or structural steel supports) shall be continuous.

9.1.5 In hydrogen service, totally enclosed spaces between attachment welds and the pressure boundary shall be eliminated or vented with a hole of 6 mm (1/4 in.) in diameter, including those spaces created by nozzle and panel liners.

9.1.6 Repair-associated welding procedures, including those that require a channel to be plugged, shall be submitted to the purchaser for approval before the start of repair.

9.1.7 For materials in sour or wet hydrogen sulfide service the weld procedure qualifications, including the need for hardness testing, shall be in accordance with NACE MR0103 or NACE MR0175, as applicable.

9.1.8 The purchaser shall specify any additional welding requirements applicable to exchangers in sour or wet hydrogen sulfide service, including the need for welding procedure qualification hardness testing and acceptance criteria when not otherwise required by NACE MR0103 or NACE MR0175, as applicable.

9.1.9 Welds used to join the following components shall be qualified in accordance with the pressure design code:

a) Heat transfer plates;

b) Plate pack to column liner and head liner;

c) Head liner to column liner;

d) Panel and nozzle liners.

9.2 Heat Treatment

9.2.1 Machined contact surfaces, including any threaded connections, shall be suitably protected to prevent scaling or loss of finish during heat treatment.

● **9.2.2** The purchaser shall specify if postweld heat treatment is required for weld-overlaid panels.

● **9.2.3** The purchaser shall specify if heat treatment is required for process reasons.

9.2.4 For sour and wet hydrogen sulfide service, the minimum postweld heat treatment requirements for carbon steel construction shall be in accordance with NACE MR0103 or NACE MR0175, as applicable.

● **9.2.5** The purchaser shall specify any additional postweld heat treatment requirements applicable to exchangers in sour or wet hydrogen sulfide service when not otherwise required by NACE MR0103 or NACE MR0175, as applicable.

9.3 Gasket Contact Surfaces Other Than Nozzle-Flange Facings

9.3.1 Final machining of gasket contact surfaces for unlined or weld overlay panels shall be done after any postweld heat treatment.

9.3.2 Gasket contact surfaces for unlined, weld overlay and integrally clad panels shall have a surface roughness of 3.2 µm to 6.3 µm (125 µin. to 250 µin.) R_a.

9.3.3 Gasket contact surfaces of panels shall be flat, with a maximum deviation along each edge of 0.8 mm (0.031 in.) for dimensions greater than 1 m (40 in.) in length, and 0.6 mm (0.024 in.) for dimensions equal to or less than 1 m (40 in.). If a liner is used, these tolerances apply to the panel surface prior to the application of the liner.

NOTE: This flatness requirement is not to be applied to the column gasket surface.

9.4 Assembly

9.4.1 Panels and fixed heads shall be provided with match marks to prevent mis-assembly.

9.4.2 The threads of external studs and nuts shall be coated with a suitable anti-seize compound to prevent galling.

10 Inspection and Testing

10.1 Quality Control

10.1.1 Each heat transfer plate shall be either vacuum tested or dye penetrant examined over their entire surface after forming and prior to welding.

10.1.2 If set-on connections are welded to plate material, the edge of the hole in the plate to which the connections are attached shall be examined for laminations by the magnetic-particle or liquid-penetrant method prior to and after completion of welding, and postweld heat treatment if applied. Subject to agreement with the purchaser, indications found shall be cleared to sound metal and then back-welded.

● **10.1.3** When specified by the purchaser, an inter-stream gas detection leak test (e.g. helium) shall be undertaken on the completed exchanger prior to pressure testing.

Unless otherwise agreed between the vendor and the purchaser, the allowable leakage rate shall be 1×10^{-8} kPa m^3/s [1×10^{-4} atm-cc/s] at a pressure difference of 100 kPa [15 psi].

● **10.1.4** The purchaser shall specify if, after welding of set-on connections, ultrasonic examination of the attachment welds and the panel shall be completed for at least 50 mm (2 in.) from the connection to the extent possible.

● **10.1.5** The purchaser shall specify whether all carbon steel plate in sour or wet hydrogen sulfide service shall be subjected to an ultrasonic lamination check (e.g. to EN 10160 grade S2E2 or ASTM A578/578M, acceptance level A supplementary requirement S1).

10.1.6 All finished carbon steel welds in sour or wet hydrogen sulfide service shall be examined on its inside surface (when accessible) by the wet-fluorescent magnetic-particle method. Weld surfaces that are determined to be inaccessible shall be agreed upon with the purchaser.

10.1.7 For pressure-retaining welds inspection and testing shall be undertaken in accordance with the pressure design code. The following additional requirements apply:

a) At least one spot-radiograph shall be made of each accessible butt-welded joint. Nozzle to nozzle flange welds are exempt from this requirement, unless required by the pressure design code.

b) Weld porosity limits for spot radiographs shall be as stated in the pressure design code for fully radiographed joints.

10.1.8 The following welds shall be liquid-penetrant examined:

a) Plate pack to column liner.

b) Plate pack to head liner (when accessible).

c) Head liner to column liner.

d) Nozzle liner.

e) Panel liner attachment.

f) Nozzle liner to panel liner.

10.1.9 Plate-to-plate welds shall be tested by one of the following methods:

a) liquid-penetrant examination;

b) submerged bubble test;

c) pneumatic soap bubble test at a gauge pressure of between 50 kPa (7.5 psi) and 100 kPa (15 psi).

10.1.10 Production weld-hardness testing of pressure-retaining welds shall be in accordance with the pressure design code, or the following requirements, whichever is the more stringent:

a) Welds in components made of carbon, Cr-Mo, 11/13/17 % chromium steels shall be hardness tested. Hardness testing of the heat-affected zone shall be conducted if required by the pressure design code, or when specified by the purchaser. Connection to component welds smaller than DN 50 (NPS 2) in size are exempted from this requirement.

b) If postweld heat treatment is required, examination shall be made after the postweld heat treatment is completed.

c) Unless otherwise agreed between the vendor and purchaser, the weld hardness for carbon steel shall not exceed 225 HBW.

d) For carbon steel welds in sour or wet hydrogen sulfide service, the production weld hardness acceptance criteria and additional testing requirements shall be specified by the purchaser.

e) Hardness readings shall be taken with a portable Brinell hardness tester. Other hardness testing techniques can be employed if approved by the purchaser. When access is available, tests shall be undertaken on the side of the weld in contact with the process fluid.

10.1.11 When weld deposit overlay is applied on pressure-retaining components, production weld chemistry tests shall be undertaken at the specified depth as follows:

a) Weld overlay test samples (including weld overlay restoration) shall be taken at a depth of at least 1.5 mm (1/16 in.) from the finished surface, unless otherwise specified by the purchaser.

b) When weld overlay is applied on nozzle assemblies, at least one deposit analysis shall be made for each welding procedure used. Where multiple nozzle assemblies are manufactured with the same welding procedure, the deposit analysis shall be taken from the smallest diameter nozzle manufactured for each welding procedure.

c) Production test locations shall be restored after testing.

10.1.12 Lifting device attachment welds shall be 100 % magnetic-particle examined.

10.2 Pressure Testing

10.2.1 The hydrostatic test shall be separately applied to the hot side and to the cold side with atmospheric pressure on the other side, in addition to a test with both sides simultaneously pressurized.

10.2.2 Each hydrostatic test shall be maintained for not less than 30 minutes after pressure stabilization.

10.2.3 For each hydrostatic test, two indicating gauges per side (or one indicating gauge and one recording gauge) shall be attached to the heat exchanger.

10.2.4 The water used for hydrostatic testing shall be potable.

10.2.5 The minimum water temperature for hydrostatic testing shall be 7 ºC (45 ºF).

10.2.6 The chloride content of the test water used for equipment with austenitic stainless steel materials that would be exposed to the test fluid, shall not exceed 50 mg/kg (50 parts per million by mass). Upon completion of the hydrostatic test, the equipment shall be promptly drained and cleared of residual test fluid.

● **10.2.7** The purchaser shall specify if paint or other coatings may be applied over welds, and any installed liners, prior to the final pressure test. See A.6 for additional information.

10.2.8 Panels removed after hydrostatic test shall be reassembled with new gaskets and pneumatically tested at a pressure between 100 kPa (ga) (15 psig) and 170 kPa (ga) (25 psig), using a soap-water solution to identify leaks at the sealing area between panels/cover plates and heads/columns.

● **10.2.9** Any additional requirements for equipment drying shall be specified by the purchaser. See A.7 for additional information.

10.3 Nameplates

10.3.1 An austenitic stainless steel nameplate shall be permanently attached to the heat exchanger in such a manner that it is visible after insulation has been installed.

10.3.2 Standard nameplate data shall include the following information:

a) manufacturer's name and heat exchanger serial number,

b) purchaser's item number,

c) year built,

d) pressure design code and, if required, code stamping,

e) maximum design temperature and minimum design metal temperature,

f) maximum design pressure and, if applicable, vacuum,

g) hydrostatic test pressure, and

h) mass (empty).

11 Preparation for Shipment

11.1 The heat exchanger shall be free of foreign matter and all openings sealed before shipment.

11.2 All liquids used for cleaning or testing shall be drained from heat exchangers before shipment. Any additional requirements for equipment drying or preservation shall be specified by the purchaser. See A.7 for additional information.

11.3 Exposed flanged connections shall be protected by either of the following:

a) gasketed steel covers fastened by the greater of

— 50 % of the required flange bolting, or

— four bolts;

b) commercially available plastic covers specifically designed for flange protection.

11.4 All flange-gasket and exposed machined surfaces shall be coated with an easily removable rust preventative.

11.5 All threaded connections shall be protected by metal plugs or caps of compatible material.

● **11.6** The purchaser shall specify if there are requirements for surface preparation and protection (e.g. painting).

11.7 Exposed threads of bolts shall be protected with an easily removable rust preventative to prevent corrosion during testing, shipping, and storage.

- **11.8** The purchaser shall specify if inert gas (e.g. nitrogen, argon) purge and fill is required. Positive pressure shall be indicated by a pressure gage. Gages shall be suitably protected from damage during transportation. The purchaser shall maintain the positive pressure of the inert gas during storage.

11.9 When an inert gas fill is used, the manufacturer shall apply a label or wired metal tag on all openings that states, “Contents are under <Inert gas> pressure and must be depressurized before opening.” All transport regulations must also be complied with.

12 Supplemental Requirements for Services Subject to High Temperature Hydrogen Service (HTHS)

12.1 General

12.1.1 The requirements of this section apply to high temperature hydrogen service. See A.8.1 for additional guidance.

12.1.2 The requirements in previous sections of this document that address hydrogen service shall be applied.

12.2 Design Temperature

12.2.1 The design temperature specified may not be the same as the temperature used for the material selection for high temperature hydrogen service. See A.8.2.

12.2.2 For a heat exchanger unit arranged in series, different design temperatures for each welded plate-block heat exchanger shall not be used unless otherwise specified by the purchaser. See A.8.2.2.

12.3 Materials

- **12.3.1** Materials, including pressure retaining components such as columns, panels, heads, and nozzles shall be specified by the purchaser in accordance with API Recommended Practice 941, including any design margins to be applied based on integrity operating window (IOW) limits. See A.8.3 and A.8.4.

12.3.2 For heat exchangers arranged in series the nominal material composition shall not vary between the different welded plate-blocks, unless specified by the purchaser.

12.4 Connections for Temperature Indication

For guidance on the use of temperature indication for individual welded plate-block heat exchangers arranged in series see A.8.5.

12.5 Fabrication

12.5.1 Weld details used on components in HTHS, including attachment welds and nozzle neck to nozzle flange butt welds, shall be full-penetration butt welds that can be 100 % volumetrically examined for the entire length.

12.5.2 All components constructed of carbon steel shall be postweld heat treated after completion of fabrication.

12.5.3 Dissimilar metal welds shall not be allowed in HTHS, except as allowed in 12.3.2. When dissimilar materials are used, the welding and PWHT procedure shall be agreed between the vendor and purchaser taking account of the varying microstructure of the weld.

12.6 Inspection and Testing

12.6.1 Positive material identification of non-carbon steel pressure part components including cladding, overlay, liners, weld consumables, panels, columns, heads, nozzles, plate packs, and completed welds shall be undertaken. The extent and method to be agreed between purchaser and vendor.

12.6.2 All butt welds shall be 100 % volumetrically examined after any required postweld heat treatment.

12.6.3 Wet fluorescent magnetic-particle examination shall be undertaken on accessible wetted surfaces, for all carbon or low-alloy steel pressure retaining welds, after any required postweld heat treatment. When the component is clad then the base material weld shall be wet fluorescent magnetic-particle examined prior to restoration of the cladding. When the minimum required preheat temperature is above the limits of wet fluorescent magnetic-particle solution, a dry magnetic-particle method may be used prior to the restoration of the cladding.

12.6.4 Production hardness testing for all pressure retaining welds and the heat-affected zones shall be undertaken in accordance with 10.1.10.

NOTE: This requirement does not apply to the plate pack and liner welds.

● **12.6.5** When specified by the purchaser, welds in HTHS (excluding the plate pack and liner welds) shall be provided with baseline UT examination reports. The extent, locations, and type of ultrasonic examination shall be as agreed with the purchaser. See API Recommended Practice 941 guidelines for ultrasonic examination inspection methods.

Annex A
(informative)

Recommended Practice

A.1 Introduction

This annex has been prepared to give advice to the designer. The advice is offered for guidance only.

The descriptions and the numbers following are those of sections of the main body of this standard.

A.2 General

A.2.1 Sour or Wet Hydrogen Sulfide Service – Guidance to 4.7 & 4.9

A.2.1.1 NACE MR0103 establishes material requirements for resistance to sulfide stress cracking (SSC) in sour petroleum refining and related process environments that contain hydrogen sulfide either as a gas or dissolved in an aqueous (liquid-water) phase, with or without the presence of hydrocarbon. SSC is defined as cracking of a metal under the combined action of tensile stress and corrosion in the presence of water and hydrogen sulfide. Other forms of wet hydrogen sulfide cracking, environmental cracking, and severely corrosive or hydrogen charging conditions that can lead to failures by mechanisms other than SSC are outside the scope of NACE MR0103.

A.2.1.2 Compared with the high pH environments of refinery sour service, oil and gas production sour environments are covered by NACE MR0175 (all parts). This is because many wet sour streams in oil and gas production facilities also contain carbon dioxide and hence exhibit a lower pH. In addition, chloride ion concentrations tend to be significantly lower in refinery sour services than in oil and gas production sour services.

A.2.1.3 NACE MR0175 (all parts) provides requirements and recommendations for the selection and qualification of metallic materials for service in equipment used in oil and gas production and natural gas processing plants in environments containing hydrogen sulfide. Mechanisms of cracking that can be caused by hydrogen sulfide include sulfide stress cracking, stress corrosion cracking (SCC), hydrogen-induced cracking (HIC), step-wise cracking (SWC), stress-oriented hydrogen-induced cracking (SOHIC), soft-zone cracking (SZC), and galvanically-induced hydrogen stress cracking (GHSC).

A.2.1.4 Factors affecting the susceptibility of metallic materials to cracking in oil and gas production facilities in environment containing hydrogen sulfide include the hydrogen sulfide partial pressure, in situ pH, the concentration of dissolved chlorides or other halides, the presence of elemental sulfur or other oxidant, temperature, galvanic effects, mechanical stress and the duration of contact with a liquid water phase.

A.2.1.5 The use of loose liners by themselves are not typically considered as adequate protection of the base materials against sour or wet hydrogen sulfide service. For this reason, the sour or wet hydrogen sulfide service requirements for materials, fabrication, and inspection are typically still applied to the base metal whenever loose liners are provided.

A.2.2 Cyclic Design – Guidance to 4.10 and 4.11

A.2.2.1 The following is guidance to assist in identifying a potential cyclic service application, where the conditions can be singular or a combination of each:

— 15 % variance in normal operating pressure;

— variation in normal operating temperature that exceeds 28 °C (50 °F);

— change in operating modes including flowrate, composition, or other conditions, can result in variations of pressure and temperature.

NOTE The variation in the normal operating temperature is suggested by API Recommended Practice 571 for critical factors for thermal fatigue.

A.2.2.2 For assistance in specifying cyclic conditions, it is suggested that the purchaser follow the guidance of ASME *BPVC, Section VIII, Division 2*, and complete a user design specification. Methodologies are also available in other pressure design codes, including EN 13445 (all parts).

A.2.2.3 It is not recommended to use welded plate-block heat exchangers in services where a fatigue analysis is necessary.

A.2.2.4 The vendor can use the screening method provided in ASME *BPVC, Section VIII, Division 2*, to determine whether a fatigue analysis is required for the given cyclic loading. If required, rules for performing a full fatigue analysis are included. Methodologies are also available in other pressure design codes including EN 13445 (all parts).

A.2.3 Operating Constraints – Guidance to 4.12

A.2.3.1 Operating Pressure Differentials

Some welded plate heat exchanger designs require a minimum operating pressure differential between streams of approximately 200 kPa (30 psi) in order to maintain the heat transfer plates in a constant state of compression. This pressure differential between the high and low pressure streams should be maintained throughout the plate pack. Should the operating pressures become equal or the differential pressure invert between the streams at a location, alternating plate flexure can occur with the plate pack behaving like an accordion. This can lead to fatigue failure over time and result in a decreased exchanger service lifetime. Occasional excursions, if not frequent in number, as may occur during start-up shut-down and other operating scenarios should not typically impact the mechanical integrity.

A.2.3.2 Start-up, Shut-down and Transient Operations

Welded plate heat exchangers are relatively compact, rigid structures and typically have more restrictive operational limitations as compared to a shell and tube heat exchanger. The exchanger, including its plate pack and baffle cage assembly, can be damaged if subjected to excessive temperature rate of change, temperature difference between streams, or pressure surges. The vendor should be consulted for specific operational limitations.

A.2.4 Failure Scenarios and Troubleshooting – Guidance to 4.13

The vendor should be consulted for guidance when performing troubleshooting and failure analysis. Typical problems include the following scenarios:

a) External leaks:

1) Gasket leakage is the most common failure mode. Improper panel tightening is often the cause. The corners of the panels are particularly sensitive to leakage. All tightening must be done in accordance with the manufacturer's instructions. Tightening in excess of the manufacturer's maximum recommended bolt torque should be avoided.

2) Panel and nozzle liner failure can result in leaks either through the nozzle tell-tale holes or through the periphery of the cover and may sometimes be mistaken for a gasket leak. When leakage is observed through tell-tale holes (see A.4.5) the unit should be shut down for liner inspection and repair. Dye penetrant testing can be used on the panel lining to assist in identifying the defect.

3) External leakage can also occur at the column and head liners resulting in fluid dripping at the bottom of the exchanger. When leakage is observed, the unit should be shut down for column liner inspection and repair.

b) Internal leaks:

Internal leaks will result in inter-stream mixing and can occur in heat transfer plates, plate-to-plate welds, plate pack to column liner attachment, or at head liner welds. When inter-stream mixing is detected, the unit should be shut down and inspected for repair in accordance with the manufacturer's recommendations.

A.3 First-time Use – Guidance to 5.4

Welded plate-block heat exchangers are normally uniquely designed for each service. The first-time use is intended to apply to the first-time application of components within a design without a history of previous service, e.g. newly developed plate patterns, method of plate pack attachment to the columns, method of welding heat transfer plates, or new gasket types that had not been previously applied or would be applied to conditions outside of prior operating experience.

A.4 Design

A.4.1 Fouling Margin – Guidance to 7.3

A.4.1.1 Conventional fouling-resistance values used with shell-and-tube heat exchangers should not be used in the thermal design of welded plate-block heat exchangers. In lieu of fouling resistances, a fouling margin is normally applied and should be considered in the thermal design of the unit. The overall fouling margin to be applied should be equal to the greater of that of the individual hot and cold fluids. Where both fluids have fouling margins equaling 15 %, the overall fouling margin should be 25 %. Recommended fouling margins for various services are included within Table A.1.

A.4.1.2 Wall shear-stress provides a good indication of fouling tendency in a welded plate-block heat exchanger. Recommended minimum wall shear-stress for services are included within Table A.1. The minimum shear stresses should be achieved at the design operating condition.

Table A.1 —Recommended Targets for Fouling Margins and Wall Shear Stress

	Fouling Margin	Wall Shear Stress (Minimum)	
	%	Pa	Psi
Demineralized water	5	-	-
Potable water	10	30	0.00435
Cooling tower water	15	50	0.00725
Dirty sea water	15	75	0.01088
Clear sea water	10	50	0.00725
Lubricating oil	10	30	0.00435
Crude oil	15	50	0.00725
Process streams, clean	10	30	0.00435
Process streams, dirty[a]	25	50	0.00725
Amine / sulfinol solutions[b]	15	50	0.00725
Steam	5	-	-
Glycol / water solutions	10	30	0.00435
Condensing process	10	-	-
Evaporating process	c	c	
Refrigerant – all phases	5	-	-

[a] If the shear stress for the process fluid can achieve 75 Pa (0.01088 psi) the fouling margin may be reduced to 20 %.

[b] Rich amine streams which are subject to vapor break-out should use the shear stress indicated for the all-liquid region.

[c] To be agreed between the purchaser and vendor.

A.4.1.3 It is desirable to increase the wall shear stress to reduce fouling tendency, but the user must note that adequate pressure drop needs to be available to achieve the required shear stress.

A.4.1.4 The fouling rate on the heat transfer surface is the difference between the deposition rate and removal rate. It is now understood that fouling can often be minimized by keeping a high fouling removal rate with higher fluid velocities. This is because a higher velocity generates higher shear stresses on the heat transfer plates. This wall shear stress drives the fouling removal rate. In welded plate-block heat exchangers the nominal channel velocities are typically low but have very-high shear stresses.

A.4.1.5 The actual wall shear stress is unknown because of the presence of eddies away from the plate wall. Therefore, a simplified shear stress calculation is used. The following formula of shear stress is for estimate purpose only. Shear stress values calculated by commercially available software may vary from the API calculation method. Users should consult with the supplier for the calculated value of the shear stress. See Figure 4 for diagrammatic view of terms used. A worked example is included in Table A.2.

The basic relationship for shear stress is:

Shear stress = Velocity head * Fanning Friction Factor

$$S = \frac{dP \times de}{4 \times L} \tag{A.1}$$

$$L = \frac{a}{w} \tag{A.2}$$

$$de = \frac{2b}{X} \tag{A.3}$$

$$a = \frac{A}{(2 \times Np \times Nch) - 1} \tag{A.4}$$

where

a is the single plate's heat transfer area [m^2 (ft^2)]

A is the total heat transfer area [m^2 (ft^2)]

b is the height to the underside of a corrugation of a plate, or ($p - t$) (See Figure 2) [mm (in.)]

de is the hydraulic diameter [mm (in.)]

dP is the channel (plate) pressure drop in the pass being analyzed [kPa (psi)]

L is the developed heat transfer length of a channel [m (ft)]

Nch is the number of flow channels per pass for each fluid

Np is the number of passes

p is the plate pitch when compressed (See Figure 4) [mm (in.)]

S is the shear stress [Pa (psi)]

t is the plate thickness [mm (in.)]

w is the flow channel width [mm (in.)]

X is the enlargement factor that increases the heat transfer surface area for the plate corrugations when compared with a flat surface. It is typically between 1.14 to 1.25 and is dependent on the specific plate being used. If the actual factor is not known, a value of 1.17 may be used as an approximation.

Based on the above equations, shear stress equation can be rearranged as follows:

$$S = C \times \left[\frac{dP \times (p - t) \times w}{2 \times a \times X} \right] \tag{A.5}$$

Where;

Constant C = 1×10^{-3}, for SI units

= 6.94×10^{-3}, for U.S. customary units

Table A.2 — Wall Shear Stress Worked Example

SI units	U.S. customary units
Given parameters (by vendor): Total number of passes: 10 t = 1.0 mm p = 5.0 mm w = 476.5 mm a = 0.2271 m^2 *Connection pressure drop* = 5 kPa *Total pressure drop* = 165 kPa X = 1.24 *(suggested value if not given)*	Given parameters (by vendor): Total number of passes: 10 t = 0.039 in. p = 0.197 in. w = 18.76 in. a = 2.44 ft^2 *Connection pressure drop* = 0.7 psi *Total pressure drop* = 23.9 psi X = 1.24 *(suggested value if not given)*
$dP = \left[\frac{Total\ pressure\ drop - Connection\ pressure\ drop}{Number\ of\ passes}\right]$ $dP = \left[\frac{165-5}{10}\right] = 16\ \mathrm{kPa}$	$dP = \left[\frac{Total\ pressure\ drop - Connection\ pressure\ drop}{Number\ of\ passes}\right]$ $dP = \left[\frac{23.9-0.7}{10}\right] = 2.3\ psi$
$S = C \times \left[\frac{dP \times (p-t) \times w}{2 \times a \times X}\right]$ $S = 1 \times 10^{-3} \times \left[\frac{16 \times (5.0-1.0) \times 476.5}{2 \times 0.2271 \times 1.24}\right]$ S = 57.3 Pa	$S = C \times \left[\frac{dP \times (p-t) \times w}{2 \times a \times X}\right]$ $S = 6.94 \times 10^{-3} \times \left[\frac{2.3 \times (0.197-0.039) \times 18.76}{2 \times 2.44 \times 1.24}\right]$ S = 0.0084 psi

A.4.1.6 The purchaser should consider installing strainers upstream of the heat exchanger to limit particles to no more than 25 % of the plate gap, or as recommended by the vendor.

A.4.2 Corrosion Allowance – Guidance to 7.4.2

The nature of their design with respect to formability and heat transfer function, the heat transfer plates are supplied in thicknesses that are typically provided in the range of 0.8 mm (1/32 in.) to 1.2 mm (3/64 in.). For this reason, the material specified for these plates must be chosen such that the anticipated corrosion rate, for the fluids contained and at the conditions of operation, is negligible to ensure the equipment's performance and pressure integrity.

A.4.3 Cleaning – Guidance to 7.5.1.2

A.4.3.1 Introduction

The welded plate-block heat exchanger can be cleaned without opening the heat exchanger by use of chemicals or water flush. Mechanical cleaning can be undertaken by opening the heat exchanger. Other cleaning methods are available such as ultrasonic or baking. Cleaning should be undertaken following the recommendations of the vendor.

A.4.3.2 Chemical Cleaning

A.4.3.2.1 Chemical cleaning may be used for lightly fouled surfaces or where the heat transfer plates are not accessible for mechanical cleaning.

A.4.3.2.2 Chemical cleaning is undertaken by circulating a suitable cleaning solution though the heat exchanger.

A.4.3.2.3 Chemical cleaning connections are typically provided on the process piping.

A.4.3.2.4 The cleaning fluid must be selected depending on the type of fouling to be removed. Prior to starting the cleaning process, the compatibility of the cleaning fluid with the plate pack and panel gasket material should be confirmed.

A.4.3.2.5 Chemical cleaning works best in the reverse direction of normal flow. When cleaning velocities or pressure drops are higher than those in normal operation, consult the manufacturer to ensure this will not damage the exchanger.

A.4.3.2.6 Unless otherwise recommended by the manufacturer the cleaning fluid flow rate should be approximately 20 % of the nominal process stream flow rate at a temperature of approximately 60 °C (140 °F) for a period of 3-4 hours.

A.4.3.2.7 The heat exchanger should be rinsed through with clean water or a neutralizing agent after the cleaning process is complete. If a neutralizing agent is used, the heat exchanger should be rinsed a second time with clean water.

A.4.3.3 Mechanical Cleaning

A.4.3.3.1 Mechanical cleaning using a high-pressure hydro-jet lance (where the heat transfer plates are accessible), may be used for highly-fouled services, or when chemical cleaning is not effective.

A.4.3.3.2 The heat exchanger orientation may require it to be rotated, or special precautions be taken, prior to mechanical cleaning. The manufacturer should be consulted to determine the mechanical cleaning requirements based on the installation orientation.

A.4.3.3.3 The following should be completed prior to removing the panels for mechanical cleaning:

- The manufacturer’s installation, operation and maintenance manual should be reviewed for disassembly instructions.
- The panels should be marked to ensure proper reinstallation.

- The internal pressure should be released.
- The fluids should be drained.

A.4.3.3.4 Where mechanical cleaning is to be undertaken for both sides, the manufacturers maintenance manual should be consulted as some equipment models may not allow for all panels to be removed simultaneously.

A.4.3.3.5 The pressure during hydro-blasting should not exceed 96,000 kPa (ga) (14,000 psig) without consulting the manufacturer.

A.4.4 Weld Overlay and Integral Cladding – Guidance to 7.5.7.4, 7.5.8.5 and 8.1.4

A.4.4.1 Typically, the panels and carbon steel connections are alloy-lined to protect against corrosion (Figure 6 a), c), or e). The panel liners extend to the outer periphery of the panel gasket as a minimum, but the panel liner is not welded along the edges to the panel. A defect in the panel or nozzle liner, or in the panel or nozzle liner welds, will cause the media to leak past the liner and contact the base metal of the panel or connection. A leak of this nature would present itself as a leak between the panels and the edge of the panel liner which is outside the gasket sealing surface. This type of leak would be indistinguishable from a gasket leak. Should a panel or nozzle liner leak be suspected, the entire surface of the liner, including all welds, should be examined by dye penetrant examination.

A.4.4.2 Weld overlay or integral cladding of the panels and connections may be considered for process services in which rapid corrosion of the base metal can occur or for lethal service applications.

A.4.4.3 When used, the weld overlay or integral cladding should extend to the outer periphery of the gasket surfaces of the panel and connection flange.

A.4.4.4 When loose liners are used, free hydrogen can become entrapped between the liner and the base material. In order to avoid accumulation of hydrogen in the void between the liner and the base metal, gaps will be required in the seal weld(s) between the liner and base metal. These gaps would serve as vents to allow trapped hydrogen to escape. The use of integrally clad or weld-overlaid construction in lieu of liners in the presence of hydrogen eliminates the void and the concerns of trapped hydrogen. The use of integrally clad or weld-overlaid construction in lieu of liners in the presence of hydrogen eliminates the void and the concerns of trapped hydrogen.

A.4.5 Tell-tale Holes – Guidance to 7.6.14

A.4.5.1 A threaded tell-tale hole in the nozzle neck may be used to provide a visual indication of leakage past the nozzle liner. They should be considered for process services in which rapid corrosion of the base metal can occur but should not be used in lethal service. When used, the size of the hole should be in accordance with the pressure design code, and the hole should be plugged prior to shipment. The plug should be removed after installation of the exchanger and fitted with a vent tube, if necessary, to allow for leakage to be detected from the outside of any insulation.

A.4.5.2 A nozzle neck tell-tale hole should not be relied upon to indicate a panel liner failure.

A.4.6 Set-on Versus Set-in Nozzles – Guidance to 7.6.3

A.4.6.1 Set-on nozzles with full penetration welds are sometimes preferred in pressure vessel construction where the panel or header thicknesses are greater than 50 mm (2 in.) and nozzle neck thicknesses are less than one half of the panel or header thickness. This avoids excessive heat input during welding that could result in deformation or damage to the nozzle neck attached with a typical full penetration set-in configuration.

A.4.6.2 Set-on connections are commonly used for welded plate-block heat exchangers as panel covers are typically much thicker than the nozzle neck. When the panel is fabricated from plate material rather than a forging, care must be taken to ensure that there are no laminations in the plate in the area of the nozzle attachment, either prior to or after the installation of the nozzle.

A.4.7 Nozzle Loads – Guidance to 7.6.14

A.4.7.1 The nozzle loads from attached piping are seldom defined at the time of order placement for a welded plate-block heat exchanger. In addition, the allowable nozzle loads for welded plate-block heat exchangers are generally lower than the calculated loads for pipe or piping flanges. It is desirable in the design stage that the heat exchanger manufacturer and piping designers work on agreed levels of nozzle loadings that can be taken by the heat exchanger. When actual piping nozzle loads become available, these should be submitted to the manufacturer to confirm their acceptability.

A.4.7.2 Nozzle loads affect nozzle attachment design, size of the heat exchanger's anchor bolts, and the design of the panels or headers; consequently, excessive loads should not be specified. Welded plate-block heat exchangers located in offshore structures or pre-assembled modules are usually required to withstand higher nozzle loadings than other facilities in which more flexible piping layouts are economical.

A.4.7.3 It is intended that the standard nozzle loads and moments given in this document be suitable for normal applications.

A.4.7.4 Some pressure design codes may require that the published pressure-temperature rating be reduced for standard nozzle flanges (e.g. ASME B16.5 and ASME B16.47) in consideration of the applied piping forces and moments. This should be considered when selecting the appropriate flange rating to be applied.

A.4.8 Panel Gaskets – Guidance to 7.7.1

A.4.8.1 After panel removal, the unit should be reassembled with new gaskets after thoroughly cleaning all gasket surfaces.

A.4.8.2 For gasket replacement, due to the unique interlocking geometry of the columns and panels, the replacement gasket should be of the same type as that originally supplied in terms of the gasket material, properties, and dimensions. If original gasket characteristics cannot be duplicated the following should be considered:

a) Increased gasket thickness can result in insufficient panel lip engagement with the mating columns and heads, resulting in leaks or mechanical failure.

b) Decreased gasket thickness can result in insufficient gasket compression and external leakage.

c) The gasket design factors (e.g. the 'm' and 'y' values from ASME *BPVC, Section VIII, Division 1*) are part of the strength calculation. Use of an alternative gasket material with higher values will have an impact on the pressure rating and should be investigated by the user.

A.5 Welding – Guidance to 9.1

Welds between heat transfer plates that are used to produce the plate pack may not be considered as pressure-retaining welds by all pressure design codes. However, the welds should always be qualified and undertaken in accordance with the pressure design code.

A.6 Painting and Applied Internal Linings—Guidance to 10.2.7

A.6.1 Set-in connections require the nozzle to be attached with welds on both the inside and outside of the panels. Painting the pressure welds after the final pressure test would require disassembly of the heat exchanger to complete the painting. The heat exchanger is reassembled after the pressure welds have been painted and a leak test will be undertaken. Painting the components, other than the pressure welds, prior to the final pressure test and then painting the pressure welds after the final pressure test may result in the “local” paint of the pressure welds not matching the quality of the other painted areas.

A.6.2 For set-in nozzle connections provided with internal liners, welds are required on both the inside and outside surfaces of the connection (see Figure 6 e), and the inside surface weld of the liner is required to allow for gasket seating on the end plate. It is not possible to perform the pressure test prior to the installation of this liner.

A.6.3 The pressure design code may permit alternative testing to ensure that painting of the pressure-retaining welds can be completed prior to the final pressure test.

A.7 Preparation for Shipment – Guidance to 10.2.9 and 11.2

A.7.1 If water residues cannot be tolerated then equipment should be dried by one of the following methods:

a) Blow the exchanger dry by the circulation of dry air or nitrogen with a maximum dew point of - 40 °C (- 40 °F), or warmed air or nitrogen at a temperature not exceeding 60 °C (140 °F), until the exit dew point is at least 5 °C (10 °F) below the ambient dew point, but in no case higher than 0 °C (32 °F).

b) Evacuating the heat exchanger with a vacuum pump to an absolute pressure of between 0.4 kPa (0.06 psi) and 0.5 kPa (0.075 psi).

A.7.2 After draining and drying, internal surfaces can be protected against corrosion by the addition of a desiccant (e.g. silica gel), by the addition of a volatile corrosion inhibitor, or by blanketing with an inert gas such as nitrogen [typically at gauge pressures up to 100 kPa (15 psi).]

A.8 Additional Considerations for Specifying Parameters for High Temperature Hydrogen Service

A.8.1 Introduction—Guidance to 12.1

HTHA is a potential material degradation mechanism that can result in surface decarburization, internal decarburization, fissuring or cracking of carbon and low alloy steels when subject to high temperature hydrogen service. For more information on HTHA, refer to API Recommended Practice 571.

A.8.2 Setting Maximum Operating or Design Temperature – Guidance to 12.2

A.8.2.1 Material selection temperatures should be made with considerations for normal operating conditions including partial pressure of hydrogen, applied safety margins, alternate operating conditions, and non-uniform fouling.

A.8.2.2 Most exchangers in services that are subject to HTHA are also subject to non-uniform fouling where the highest rate of the fouling occurs at the hot end of the process. In practice, design fouling factors used for initial design do not reflect this phenomena and fouling is applied as uniform across the exchanger. Operating data, if available, should be evaluated for non-uniform fouling trends and be applied to designs in similar services. Where historical data is not available, the designer should consider the effects of higher rates of hot-end fouling when predicting maximum exposure temperatures.

Similarly, if there are heat exchangers in series in high temperature service, designers sometimes assume operating conditions over the life of the plant based on the maximum expected degree of fouling. However, if the hottest exchanger in the series fouls more than expected and no longer cools the process stream sufficiently, the next exchanger(s) in the series might see higher temperatures than it was designed for. It may then become susceptible to HTHA or other damage mechanisms for which the materials of construction may not be suitable. For additional information on damage mechanisms see API Recommended Practice 571.

A.8.2.3 Clean exchanger performance should be evaluated in the temperature analysis. When operating in the clean condition, the cold stream would be expected to exit the heat exchanger at temperatures above the expected process operating temperature unless external temperature controls are used.

A.8.2.4 When a hot bypass is required for process conditions (i.e. temperature control around the exchanger), the exchanger on the downstream side of the reintroduction of the bypass of the hot fluid requires detailed analysis to account for the uncooled material flowing through the bypass line. If a flow bypass is not accounted for, then the downstream equipment on the hot fluid side may be exposed to unanticipated and undetected material degradation. Analysis of temperatures is required in both clean and fouled operating conditions.

A.8.2.5 When a cold bypass is required for hot stream outlet temperature control, in addition to A.8.2.4, the equipment requires a detailed analysis to account for the additional heating and higher outlet temperature of the cold fluid that passes through the exchanger, prior to remixing with the by-pass stream. This can result in the exchanger operating above the material limits since the cooling fluid has been limited. Temperatures should be analyzed in both clean and fouled operating conditions.

A.8.3 Materials Selection for HTHA Services – Guidance to 12.3

A.8.3.1 Columns, panels, heads, and nozzles in HTHS should be selected in accordance with API Recommended Practice 941. All other applicable damage mechanisms should also be reviewed for the final materials selection. For additional information on damage mechanisms see API Recommended Practice 571.

A.8.3.2 All operating modes should be considered to define the temperature and hydrogen partial pressure to be used in selecting materials per API Recommended Practice 941.

A.8.3.3 A safety margin may be applied when using the API Recommended Practice 941 curves, primarily as the curves are based on experience-based data. This margin can, where available, be based on user experience or practices. If a clad or weld-overlaid material is used, the base material should be resistant to the hydrogen conditions with no credit taken for the cladding or overlay.

A.8.4 Establishing Integrity Operating Window (IOW) for Services Subject to HTHA – Guidance to 12.3.1

A.8.4.1 The establishment, monitoring, and maintaining of IOWs is a vital component of integrity management to control and prevent material degradation and assist in the exchanger inspection planning process, including risk-based inspection. See API Recommended Practice 941 and API Recommended Practice 584.

A.8.4.2 Monitoring of equipment subject to HTHA requires that both chemical and physical operating parameters be examined including operating pressure, hydrogen partial pressure, and temperatures at specific locations of interest based on the exchanger and system design parameters and metallurgy.

A.8.4.3 As HTHA is a time-dependent degradation mechanism, a Standard IOW Limit is typically applied. If this limit is exceeded over a specified period of time, increased degradation rates or new damage mechanisms could be experienced. Therefore, exceeding Standard IOW Limits may be acceptable over a specified (limited) period of time. All such cases should be tracked to understand the cumulative effect.

There may be cases where the exchanger mechanical design temperature(s) are higher than the temperatures indicated in the equipment IOWs. Care must be exercised to refer to the IOW temperature limits and not only the mechanical design temperatures when considering operating temperature changes for exchangers in high temperature hydrogen service.

IOW Critical Limits are also applied if this limit is exceeded rapid deterioration could occur. When IOW critical limits are exceeded, an alarm is generated and immediate action is required to return the process variable(s) to within their IOW.

A.8.4.4 The establishment of IOW parameter limits for new heat exchangers in terms of operating temperature and hydrogen partial pressure for exchangers in HTHS depend upon many factors including the following:

a) Materials of construction and any heat treatment applied.

b) Previous history of HTHA for the intended service.

c) Safety margins that are applied to the API Recommended Practice 941 guidelines for the selection of materials.

d) Purchaser's philosophy with respect to allowable duration of short-term exceedances of operating parameters used for material selection, e.g. end of run operation or catalyst sulfiding, etc.

e) The length of time that equipment will be exposed to extreme or off normal operating conditions.

f) Location and accuracy of temperature monitoring devices with respect to critical locations of temperature and/or materials of construction breaks, including influence of hot/cold stream by-passes.

g) Effectiveness and rigor of heat exchanger/process monitoring program with respect to being able to accurately predict metal temperatures at specific locations where direct temperature indication is not available, including the consideration of non-linear heat exchanger fouling.

For more information on IOWs, refer to API Recommended Practice 584.

A.8.5 Intermediate Temperature Connections – Guidance to 12.4

A.8.5.1 The installation of temperature recording devices is essential for monitoring temperature trends between individual welded plate-block heat exchangers to ensure operating within the IOW limits.

A.8.5.2 For a heat exchanger unit arranged in series, where there are varying design temperatures or metallurgy, flanged connections for temperature indication should be provided for the side(s) in HTHS. These may be provided in the interconnecting nozzles or interconnecting piping.

Annex B
(informative)

Welded Plate-block Heat Exchanger Checklist

Completion of the checklist (Table B.1) is the responsibility of the purchaser.

The checklist is used for listing the purchaser's specific requirements for which the paragraphs or subsections within this standard include a choice or which designate, by use of a bullet [●] in the margin, that a decision is required.

Table B.1 - Checklist

Section	Requirement	Item		
4.1	Specify (or agree) pressure design code	Complete on datasheet		
4.2	Specify (or agree) structural welding code	Complete on datasheet		
4.6	Compliance with applicable local regulations	Complete on datasheet		
4.7	Is the unit subject to sour or wet hydrogen sulfide service on the hot side?	Yes	No	
	Is the unit subject to sour or wet hydrogen sulfide service on the cold side?	Yes	No	
4.8	Specify if the hot side is in hydrogen service.	Yes	No	
	Specify if the cold side is in hydrogen service.	Yes	No	
4.9	Are requirements for sour or wet hydrogen sulfide service to be applied where carbon steel is lined?	Yes (specify per stream)	No	
4.10	Is cyclic design service required? If yes provide detailed information.	Yes (provide requirements)	No	
4.14	Specify if the hot side is to be accessible for mechanical cleaning.	Yes	No	
	Specify if the cold side is to be accessible for mechanical cleaning.	Yes	No	
6.2.3	Copies required of applicable welding procedure specifications, procedure qualifications and weld map.	For review	For record	Not required
6.2.4	Copies required of mechanical design calculations including for supports, lifting and pulling devices.	For review	For record	Not required
6.2.5	Specify if information about quality control system required, and if quality control plan required.	For review	For record	Not required
6.2.6	Copies required of applicable interstream and external leak testing procedures.	For review	For record	Not required
6.3	Specify the format and quantities for the listed final documentation.	Provide requirements		

Section	Requirement	Item	
7.1.1	Specify a maximum design temperature and a MDMT for hot and cold sides	Complete on datasheet	
7.3	Specify fouling margin	Complete on datasheet	
7.4.1	Specify corrosion allowance	Complete on datasheet for applicable components	
7.5.7.4	Specify if panels to be weld overlay, integrally clad, or explosion bonded.	Complete on datasheet	
7.5.8.4	Specify if nozzles to be weld overlay or integrally clad.	Complete on datasheet	
7.6.2	Specify if studded or flanged connections required and the required flange design code.	Complete on datasheet	
7.6.7	Is insulation required? If yes, specify insulation. thickness.	Complete on datasheet	
7.6.8	Specify if chemical cleaning connections required? If yes, specify size, number, and locations.	Complete on datasheet	
7.6.14	Specify if a tell-tale hole required on bottom of nozzle necks.	Yes	No
7.7.1.2	Specify if the panel gasket shall be confined on both the outer and inner perimeter.	Complete on datasheet	
8.1.3	Specify materials for all components in contact with the process fluid.	Complete on datasheet	
8.2.3	Specify restrictions on residual elements and micro-alloying elements for carbon steel components in sour or wet hydrogen sulfide service.	Complete on datasheet	
9.2.2	Specify if postweld heat treatment is required for weld-overlaid panels.	Yes	No
9.2.3	Specify if heat treatment is required for process reasons.	Yes	No
10.1.3	Specify if an inter-stream gas detection leak test is required after hydrostatic testing. Specify type required.	Complete on datasheet	
10.1.4	Specify if set-on nozzle attachments are to be ultrasonically examined.	Yes	No
10.1.5	Specify if all carbon steel plate in sour or wet hydrogen sulfide service shall require UT lamination check	Yes	No
10.2.7	Specify if paint or other coatings may be applied over welds, and any installed liners, prior to the final pressure test	Yes	No
10.2.9	Specify any additional requirements for equipment drying or preservation.	Complete on datasheet	
11.6	Specify any additional requirements for surface preparation and protection (e.g. painting). If yes, provide requirements.	Yes (provide requirement)	No
11.8	Specify if inert gas purge and fill is required.	Yes	No
12.3.1	Specify if the nominal composition of construction of the wetted surfaces of either or both the hot side and cold side vary. If yes, provide detailed information.	Either	Both

Section	Requirement	Item	
12.6.5	Specify if welds shall be provided with baseline UT examination reports. If yes, detailed information to be agreed	Yes	No

Annex C
(informative)

Welded Plate-block Heat Exchanger Datasheets

The following datasheets are provided to assist the designers, vendors, and purchasers in specifying the data necessary for the design of a welded plate-block heat exchanger for petroleum and natural gas services. Entries that are not relevant to a welded plate-block heat exchangers should be annotated as "N/A."

Completion of the datasheet is a joint responsibility of the purchaser and the vendor. The purchaser (owner or contractor) is responsible for the process data, which define the purchaser's explicit requirements.

After the exchanger has been fabricated, the vendor should complete the datasheets to make a permanent record that accurately describes the equipment "as-built."

Additional datasheets may be required to define the welded plate-block heat exchanger, and examples are included in this annex:

— Page 3: Physical properties. These are used if the designer/user requires such level of data to undertake the thermal design. These sections may not be necessary if pages 1 and 2 define the information sufficiently.

— Page 4: Additional cyclic service design data. This is required only for exchangers where the unit is subject to cyclic service.

Company	WELDED PLATE-BLOCK HEAT EXCHANGER DATASHEET (SI UNITS) PROCESS	Engineering contractor
P.O. No.:	**Doc. No.:**	**Page 1 of**

1	Client:		Location:			
2	Process unit:		Item No.:			
3	Job No.:		Fabricator:			
4	Service of unit:		No. of units:			
5	Size		Connected in:		Parallel	Series
6	Total effective heat transfer area:	m^2				
7	**CASE**		**HOT SIDE**		**COLD SIDE**	
8	Fluid name					
9	Total flow	(kg/s)				
10	Flow per exchanger	(kg/s)				
11	Design temperature (maximum)	(°C)				
12	Minimum design metal temperature	(°C)				
13	Design pressure	[kPa (ga)]				
14	Pressure drop allow able / calculated	(kPa)	/		/	
15	Wall temperature minimum / maximum	(°C)	/		/	
16	Fouling margin [a]	(%)				
17	**OPERATING DATA**		**INLET**	**OUTLET**	**INLET**	**OUTLET**
18	Liquid flow	(kg/s)				
19	Vapor flow	(kg/s)				
20	Noncondensables flow	(kg/s)				
21	Operating temperature	(°C)				
22	Operating pressure	[kPa (ga)]				
23	**LIQUID PROPERTIES**					
24	Density	(kg/m^3)				
25	Specific heat capacity	(kJ/kg·K)				
26	Dynamic viscosity	(mPa·s)				
27	Thermal conductivity	(W/m·K)				
28	Surface tension	(N/m)				
29	**VAPOR PROPERTIES**					
30	Density	(kg/m^3)				
31	Specific heat capacity	(kJ/kg·K)				
32	Dynamic viscosity	(mPa·s)				
33	Thermal conductivity	(W/m·K)				
34	Relative molecular mass	(kg/kmol)				
35	Relative molecular mass, noncondensables	(kg/kmol)				
36	Dew point / bubble point	(°C)				
37	Solids maximum size	(mm)				
38	Solids concentration (% volume)					
39	Latent heat	(kJ/kg)				
40	Critical pressure	[kPa (abs)]				
41	Critical temperature	(°C)				
42	Total heat exchanged	(kW)				
43	U [a]	($W/m^2·K$)	Clean Condition		Service	
44	LMTD	(°C)	/			
45	Heat transfer area	(m^2)				
46	Stream heat transfer coefficient	($W/m^2·K$)				
47	[a] Fouling margin = $[(U_{clean}/U_{service}) - 1]$ x 100 % w here U = Overall heat transfer coefficient (thermal transmittance).					
48	NOTES:					
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Rev. No.	Description	Date	Prepared by	Review ed by

Company	WELDED PLATE-BLOCK HEAT EXCHANGER DATASHEET (SI UNITS) MECHANICAL	Engineering contractor
P.O. No.:	**Doc. No.:**	**Page 2 of**

1	**CONFIGURATION FOR EXCHANGER AND HEAT TRANSFER PLATE DETAILS**					
2	Number of exchangers in parallel		Heat transfer area/total (mm^2)			
3	Number of exchangers in series		Heat transfer area per plate (mm^2)			
4	Number of passes, hot side		Number of plates per exchangers			
5	Number of passes, cold side		Nominal plate size (mm)			
6	Relative directions of fluids	Cocurrent ( ) Countercurrent ( )	Plate chevron angle(s)			
7	Nominal plate gap (mm)		Nominal plate thickness (mm)			
8	**DESIGN DATA**					
9	Pressure vessel code					
10	Material certificate type					
11	Code stamp	Yes ( )	No ( )			
12	Applicable specifications					
13	Local rules and regulations					
14	Local register of exchanger					
15		**HOT SIDE**		**COLD SIDE**		
16	Test pressure [kPa (ga)]					
17	MAWP [kPa (ga)]					
18	Velocity between plates (m/s)					
19	Wall shear-stress (Pa)					
20	Volume liquid per exchanger (m^3)					
21	Length / width / height (mm)	/		/		
22	Mass empty / full of water (kg)	/				
23	**CONNECTIONS**	**IN**	**OUT**	**IN**	**OUT**	
24	Nozzle size (DN)					
25	Flange rating / type	/	/	/	/	
26	Vent and drain (NPS)					
27	**COMPONENTS**	**MATERIALS**				
28	Heat transfer plates					
29	Panels / panel liners	/				
30	Columns / column liners	/				
31	Baffles	/				
32	Fixed head / head liner					
33	Panel gaskets	Hot side		Cold side		
34	Connection design	Set-in ( )	Set-on ( )	Studded ( )	Flanged nozzles ( )	
35	Nozzle pipes / flanges					
36	Corrosion allowance on connections (mm)					
37	Stud bolts / nuts					
38	Shroud	None ( )	Spray ( )	Fire ( )		
39	Drip tray	Yes ( )	No ( )	By others ( )		
40	Painting specification	Manufacturers std. ( )		Purchasers std. ( )		
41	Insulation	Yes ( )	No ( )	By others ( )		
42	**LOADING**					
43	Connection loads / moments	Standard ( )		Purchaser specification ( )		
44	Wind loading					
45	Explosion blast pressure					
46	Earthquake loading					
47	Transport loading at sea		Offshore installation loading			
48	**TESTING AND INSPECTION**					
49	Nondestructive testing in addition to the pressure design code	Yes ( ) No ( )	Dried by blowing air	Yes ( )	No ( )	
50	Inspection required	Purchaser ( )		Third party ( )		
51	Shipment preservation	Desiccant ( )	Volatile Corrosion Inhibitor ( )	Inert Gas Blanketing ( )		
52	Specific drying procedure	Yes ( )	No ( )	Dried by blowing air	Yes ( )	No ( )

Rev. No.	Description	Date	Prepared by	Reviewed by

Company	WELDED PLATE-BLOCK HEAT EXCHANGER DATASHEET (SI UNITS) PHYSICAL PROPERTIES	Engineering contractor
P.O. No.:	**Doc. No.:**	**Page 3 of**

1	**PHYSICAL PROPERTIES**									
2	**(INCLUDING WATER IF PRESENT)**									
3	**CASE**									
4	Temperature	(°C)								
5	Presssure	[kPa (abs)]								
6	Heat Released	(kW)								
7	**LIQUID PHASE**									
8	Mass fraction vapor									
9	Mass fraction H_2O in liquid									
10	Density	(kg/m^3)								
11	Specific heat capacity	(kJ/kg·K)								
12	Dynamic viscosity	(mPa·s)								
13	Thermal conductivity	(W/m·K)								
14	Surface tension	(N/m)								
15	Vapor pressure	[kPa (abs)]								
16	**VAPOR PHASE**									
17	Density	(kg/m^3)								
18	Specific heat capacity	(kJ/kg·K)								
19	Dynamic viscosity	(mPa·s)								
20	Thermal conductivity	(W/m·K)								
21	Vapor pressure	[kPa (abs)]								
22	Relative molecular mass	(kg/kmol)								
23	Latent heat	(kJ/kg)								
24	Critical pressure	[kPa (abs)]								
25	Critical temperature	(°C)								
26	**NOTES**									
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Rev. No.	Description	Date	Prepared by	Review ed by

Company	WELDED PLATE-BLOCK HEAT EXCHANGER DATASHEET (SI UNITS) CYCLIC SERVICE INFORMATION	Engineering contractor
P.O. No.:	**Doc. No.:**	**Page 4 of**

Description of Cyclic Service Operation

Condition	Time (h/min)	Duration (h/min)	**Composition**	**Flow rate** (kg/h)

Condition	Time (h/min)	Duration (h/min)	**Temperature** (°C)	**Pressure** [kPa(g)]

NOTES

Rev. No.	Description	Date	Prepared by	Review ed by

Company	**WELDED PLATE-BLOCK HEAT EXCHANGER DATASHEET (US CUSTOMARY UNITS) PROCESS**	Engineering contractor
P.O. No.:	**Doc. No.:**	**Page 1 of**

1	Client:		Location:			
2	Process unit:		Item No.:			
3	Job No.:		Fabricator:			
4	Service of unit:		No. of units:			
5	Size		Connected in:		Parallel	Series
6	Total effective heat transfer area:	ft^2				
7	**CASE**		**HOT SIDE**		**COLD SIDE**	
8	Fluid name					
9	Total flow	(lb/h)				
10	Flow per exchanger	(lb/h)				
11	Design temperature (maximum)	(°F)				
12	Minimum design metal temperature	(°F)				
13	Design pressure	(psig)				
14	Pressure drop allow able / calculated	(psi)	/		/	
15	Wall temperature minimum / maximum	(°F)	/		/	
16	Fouling margin [a]	(%)				
17	**OPERATING DATA**		**INLET**	**OUTLET**	**INLET**	**OUTLET**
18	Liquid flow	(lb/h)				
19	Vapor flow	(lb/h)				
20	Noncondensables flow	(lb/h)				
21	Operating temperature	(°F)				
22	Operating pressure	(psig)				
23	**LIQUID PROPERTIES**					
24	Density	(lb/ft^3)				
25	Specific heat capacity	(BTU/lb·R)				
26	Dynamic viscosity	(cP)				
27	Thermal conductivity	(BTU/ft·h·°R)				
28	Surface tension	(Dynes/cm)				
29	**VAPOR PROPERTIES**					
30	Density	(lb/ft^3)				
31	Specific heat capacity	(BTU/lb·R)				
32	Dynamic viscosity	(cP)				
33	Thermal conductivity	(BTU/ft·h·°R)				
34	Relative molecular mass	(lb/lb·mol)				
35	Relative molecular mass, noncondensables	(lb/lb·mol)				
36	Dew point / bubble point	(°F)				
37	Solids maximum size	(in.)				
38	Solids concentration (% volume)					
39	Latent heat	(BTU/lb)				
40	Critical pressure	(psia)				
41	Critical temperature	(°F)				
42	Total heat exchanged	(BTU/h)				
43	U [a]	(BTU/h·ft^2·°R)	Clean Condition		Service	
44	LMTD	(°F)	/			
45	Heat transfer area	(ft^2)				
46	Stream heat transfer coefficient	(BTU/h·ft^2·°R)				
47	[a] Fouling margin = $[(U_{clean}/U_{service}) - 1] \times 100$ % w here U = Overall heat transfer coefficient (thermal transmittance).					
48	NOTES:					
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Rev. No.	Description	Date	Prepared by	Review ed by

Company	WELDED PLATE-BLOCK HEAT EXCHANGER DATASHEET (US CUSTOMARY UNITS) MECHANICAL	Engineering contractor
P.O. No.:	**Doc. No.:**	**Page 2 of**

1	**CONFIGURATION FOR EXCHANGER AND HEAT TRANSFER PLATE DETAILS**				
2	Number of exchangers in parallel			Heat transfer area/total (ft^2)	
3	Number of exchangers in series			Heat transfer area per plate (ft^2)	
4	Number of passes, hot side			Number of plates per exchangers	
5	Number of passes, cold side			Nominal plate size (in.)	
6	Relative directions of fluids	Cocurrent ( )	Countercurrent ( )	Plate chevron angle(s)	
7	Nominal plate gap (in.)			Nominal plate thickness (in.)	

8	**DESIGN DATA**				
9	Pressure vessel code				
10	Material certificate type				
11	Code stamp	Yes ( )	No ( )		
12	Applicable specifications				
13	Local rules and regulations				
14	Local register of exchanger				
15		**HOT SIDE**		**COLD SIDE**	
16	Test pressure (psig)				
17	MAWP (psig)				
18	Velocity between plates (ft/s)				
19	Wall shear-stress (psi)				
20	Volume liquid per exchanger (ft^3)				
21	Length / width/height (in.)	/		/	
22	Mass empty / full of water (lb)	/			
23	**CONNECTIONS**	**IN**	**OUT**	**IN**	**OUT**
24	Nozzle size (NPS)				
25	Flange rating / type	/	/	/	/
26	Vent and drain (NPS)				
27	**COMPONENTS**	**MATERIALS**			
28	Heat transfer plates				
29	Panels / panel liners	/			
30	Columns / column liners	/			
31	Baffles	/			
32	Fixed head / head liner				
33	Panel gaskets	Hot side		Cold side	
34	Connection design	Set-in ( )	Set-on ( )	Studded ( )	Flanged nozzles ( )
35	Nozzle pipes / flanges				
36	Corrosion allowance on connections (in.)				
37	Stud bolts / nuts				
38	Shroud	None ( )	Spray ( )	Fire ( )	
39	Drip tray	Yes ( )	No ( )	By others ( )	
40	Painting specification	Manufacturers std. ( )		Purchasers std. ( )	
41	Insulation	Yes ( )	No ( )	By others ( )	
42	**LOADING**				
43	Connection loads/moments	Standard ( )		Purchaser specification ( )	
44	Wind loading				
45	Explosion blast pressure				
46	Earthquake loading				
47	Transport loading at sea		Offshore installation loading		
48	**TESTING AND INSPECTION**				
49	Nondestructive testing in addition to the pressure design code	Yes ( ) No ( )	Dried by blowing air	Yes ( )	No ( )
50	Inspection required	Purchaser ( )		Third party ( )	
51	Shipment preservation	Desiccant ( )	Volatile Corrosion Inhibitor ( )	Inert Gas Blanketing ( )	
52	Specific drying procedure	Yes ( )	No ( )	Dried by blowing air	Yes ( ) No ( )

Rev. No.	Description	Date	Prepared by	Reviewed by

Company	WELDED PLATE-BLOCK HEAT EXCHANGER DATASHEET (US CUSTOMARY UNITS) PHYSICAL PROPERTIES	Engineering contractor

P.O. No.:	Doc. No.:	Page 3 of

1	**PHYSICAL PROPERTIES**										
2	**(INCLUDING WATER IF PRESENT)**										
3	**CASE**										
4	Temperature	(°F)									
5	Presssure	(psia)									
6	Heat Released	(BTU/h)									
7	**LIQUID PHASE**										
8	Mass fraction vapor										
9	Mass fraction H_2O in liquid										
10	Density	(lb/ft^3)									
11	Specific heat capacity	(BTU/lb·°R)									
12	Dynamic viscosity	(cP)									
13	Thermal conductivity	(BTU/h·ft·°R)									
14	Surface tension	(Dynes/cm)									
15	Vapor pressure	(psia)									
16	**VAPOR PHASE**										
17	Density	(lb/ft^3)									
18	Specific heat capacity	(BTU/lb·°R)									
19	Dynamic viscosity	(cP)									
20	Thermal conductivity	(BTU/h·ft·°R)									
21	Vapor pressure	(psia)									
22	Relative molecular mass	(lb/lb·mol)									
23	Latent heat	(BTU/lb)									
24	Critical pressure	(psia)									
25	Critical temperature	(°F)									
26	**NOTES**										
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Rev. No.	Description	Date	Prepared by	Review ed by

Company	WELDED PLATE-BLOCK HEAT EXCHANGER DATASHEET (US CUSTOMARY UNITS) CYCLIC SERVICE INFORMATION	Engineering contractor
P.O. No.:	Doc. No.:	Page 4 of

Description of Cyclic Service Operation

Condition	Time (h/min)	Duration (h/min)	Composition	Flow rate (lb/h)

Condition	Time (h/min)	Duration (h/min)	Temperature (°F)	Pressure (psig)

NOTES

Rev. No.	Description	Date	Prepared by	Review ed by

Bibliography

[1] API Recommended Practice 571, *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry*

[2] API Recommended Practice 584, *Integrity Operating Windows*

[3] API Standard 667, *Plate-and-frame Heat Exchangers*

[4] ASME B16.5, *Pipe Flanges and Flanged Fittings*

[5] ASME B16.47, *Large Diameter Steel Flanges NPS 26 Through NPS 60 Metric/Inch Standard*

[6] ASME *Boiler and Pressure Vessel Code (BPVC), Section II: Materials*

[7] ASME *Boiler and Pressure Vessel Code (BPVC), Section VIII: Rules for Construction of Pressure Vessels; Division 1*

[8] ASME *Boiler and Pressure Vessel Code (BPVC)*, *Section VIII: Rules for Construction of Pressure Vessels*; *Division 2: Alternative Rules*

[9] ASTM A578/578M,[3] *Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications*

[10] EN 10160, [4] *Ultrasonic Testing of Steel Flat Product of Thickness Equal or Greater Than 6 mm (Reflection Method)*

[11] EN 13445, (all parts), *Unfired pressure vessels*

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[3] ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, Pennsylvania 19428-2959, U.S.A., www.astm.org

[4] European Committee for Standardization, Rue de la Science 23, B-1040, Brussels, Belgium, www.cencenelec.eu.