Brazed Aluminum Plate-fin Heat Exchangers

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BALLOT DRAFT

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Introduction

It is necessary that users of this standard should be aware that further or differing requirements may be necessary 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.

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, US Customary units are included in parentheses for information.

Brazed Aluminum Plate-fin Heat Exchangers

1 Scope

This standard gives requirements and recommendations for the mechanical design, materials selection, fabrication, inspection, testing, and preparation for shipment of brazed aluminum plate-fin heat exchangers for use in the petroleum, petrochemical, and natural gas industries.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

ALPEMA[1] , *The Standards of the Brazed Aluminum Plate-Fin Heat Exchanger Manufacturers' Association*

NOTE In this standard, this normative reference will be referred to in the text as the "ALPEMA *Standards*" due to its lengthy title and multiple citations.

ASME *Boiler and Pressure Vessel Code (BPVC)*[2] *, Section VIII, Division 1: Rules for construction of pressure vessels*

ASME *Boiler and Pressure Vessel Code (BPVC)*[3] *, Section VIII, Division 1: Rules for construction of pressure vessels, Code Case 2493*

ASME *Boiler and Pressure Vessel Code (BPVC)*[4] *Section VIII, Division 2: Rules for construction of pressure vessels*
ASME B16.5, *Pipe Flanges and Flanged Fittings NPS ¹⁄₂ through NPS 24 Metric/Inch Standard*

ASME B16.9, *Factory-Made Wrought Buttwelding Fittings*

ASME B16.25, *Buttwelding Ends*

ASME B16.47, *Large Diameter Steel Flanges: NPS 26 through NPS 60*

ASME B31.3, *Process Piping, 2020 Edition*

3 Terms and Definitions

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

3.1
block
core
An assembly consisting of alternating layers (passages) of corrugated fins, separated by parting sheets and sealed along their edges by means of side bars and end bars, and bounded by cap sheets, which are brazed to become a rigid structure.

3.2
block-in-shell heat exchanger
A heat exchanger system consisting of one or more plate-fin heat exchangers installed within a pressure vessel shell.

3.3

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[1] Brazed Aluminum Plate-Fin Heat Exchanger Manufacturers' Association, www.alpema.org. (Secretariat services provided by Heat Transfer Research Inc., P.O. Box 1390, Navasota, TX 77868, www.htri.net)

[2] American Society of Mechanical Engineers, Two Park Avenue, New York City, NY 10016-5990, www.asme.org.

[3] American Society of Mechanical Engineers, Two Park Avenue, New York City, NY 10016-5990, www.asme.org.

[4] American Society of Mechanical Engineers, Two Park Avenue, New York City, NY 10016-5990, www.asme.org.

cold box

An enclosure consisting of a carbon steel casing, usually rectangular in shape, that supports and houses plate-fin heat exchangers, pressure vessels, piping, and other cryogenic equipment, filled with insulation and operated under an inert atmosphere.

3.4

cyclic service

Services which as part of their intended operation are subjected to the application of fluctuating mechanical and/or thermal loads, which must be considered in the mechanical design.

EXAMPLE Exchangers in batch operating service, exchangers in intermittent service, exchangers used as part of reactor catalyst regeneration systems, exchangers with different modes of operations, etc.

3.5

full-penetration weld

A welded joint that results in weld metal through the entire thickness of the components being joined.

3.6

heat transfer area

The sum of the primary and secondary heat transfer surface areas of all heat-transfer passages in contact with a stream. See Figure 1.

NOTE 1 The primary heat transfer surface within the plate-fin heat exchanger consists of the bare parting sheet and the fin base directly brazed to the parting sheet.

NOTE 2 The secondary heat transfer surface is provided by the fins. This area includes both sides of the fins where they are in contact with the fluid.

Key

1 primary heat transfer surface
2 secondary heat transfer surface
3 parting sheet
4 fin

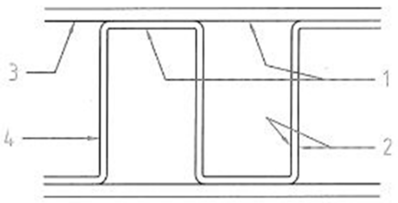


Figure 1—Cross-sectional View of Fin and Parting Sheet
(Figure provided courtesy of ALPEMA)

3.7

hydrogen service

Services that contain hydrogen at a partial pressure exceeding 350 kPa (50 psi) absolute.

3.8

item number

The purchaser’s identification number for a plate-fin heat exchanger.

3.9

minimum design metal temperature

MDMT

The lowest metal temperature at which pressure-containing elements can be subjected to design pressure.

EXAMPLES Ambient temperature and process fluid temperature.

3.10

modular core

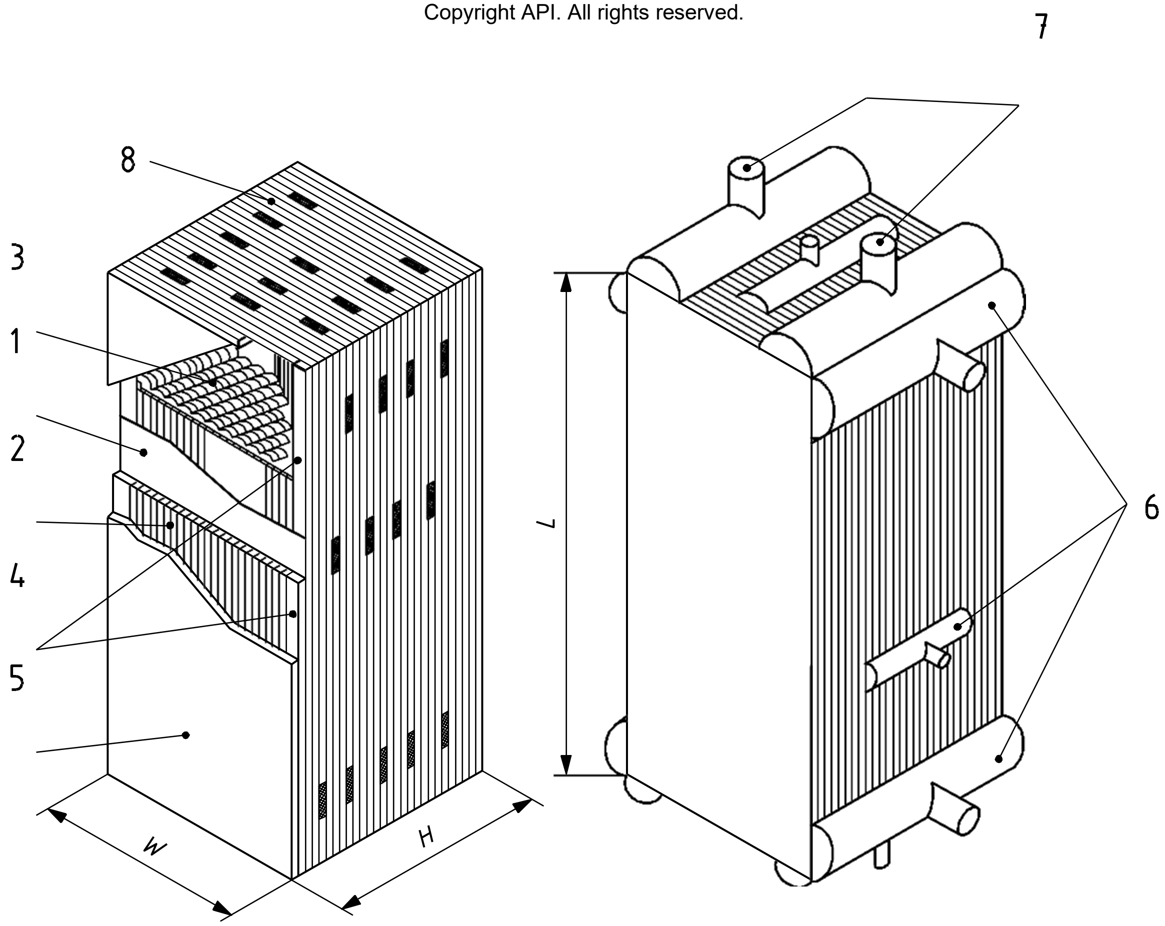
An assembly of two or more individually brazed blocks (cores) that have been welded together in parallel to form one composite block.

3.11
plate-fin heat exchanger

A heat exchanger consisting of a block to which headers and nozzles have been attached. See Figure 2.

NOTE 1 The layers are separated from each other by parting sheets and sealed along the edges by means of side bars and end bars, and are provided with inlet and outlet ports for the streams. The block is bounded by cap sheets at the top and bottom.

NOTE 2 All the layers carrying the same stream are connected by headers (inlet, outlet, intermediate) directly attached by welding onto the block.



Key

H = height
L = length
W = width

1 parting sheet
2 heat transfer fins
3 distributor fins
4 side bars

5 cap sheet
6 headers
7 nozzles
8 block

Figure 2—Typical Components of a Brazed Aluminum Plate-Fin Heat Exchanger
(Figure provided courtesy of ALPEMA)

3.12
pressure design code
Recognized pressure vessel standard specified or agreed by the purchaser.

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

3.13
separator vessel
A pressure vessel provided to separate liquid and vapor phases of a two-phase stream prior to the introduction of these phases into a brazed aluminum plate-fin heat exchanger.

3.14
shipping plug
A temporary sealing device used to close vent and drain holes in unpressurized areas of plate-fin-heat exchangers during shipping, handling, and storage. The purpose of the shipping plug is to prevent ingress of moisture and debris.

3.15
structural welding code

Recognized structural welding code specified or agreed by the purchaser.

3.16
transition joint
A prefabricated, non-separable, metallurgically bonded joint used for the connection of dissimilar metal piping components which are not weldable to each other, e.g., between aluminum piping and stainless steel piping.

3.17
vent line
A pipe or tube connected to vent and drain holes of unpressurized areas after the removal of shipping plugs. Typically, vent lines are not used for blocks installed inside the cold box.

4 General Requirements

● **4.1** The pressure design code shall be specified or agreed by the purchaser. Pressure components 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** The vendor shall comply with the applicable local regulations specified by the purchaser.

● **4.4** The purchaser shall specify if the heat exchanger is in cyclic service. For assistance see A.2.1.

● **4.5** The purchaser shall specify the quantity of mercury, organo-mercuric compounds, and heavy metals that will be present in the fluids in contact with the plate-fin heat exchanger. If water is present, the purchaser shall also specify the quantity of H_2S, NH_3, CO_2, SO_2, NO_X, CO, Cl, the presence of halides, and the pH value. The purchaser shall identify any streams for which a mercury-tolerant design is required. See A.2.2 for additional guidance.

4.6 If cyclic service is specified, the purchaser shall specify the type and magnitude of variations in pressure and/or temperature expected during exchanger operation, including the duration and number of cycles or frequency of these variations which are anticipated over the specified design life of the equipment. When process operating conditions, including flow rates and fluid temperatures vary over operation, sufficient information shall be provided to allow for the resulting mechanical and thermal stresses to be determined. The extent and acceptance criteria of any required fatigue assessment and analysis shall be subject to the agreement of the purchaser. See A.2.1 for guidance on cyclic service.

● **4.7** The purchaser shall specify if any of the streams are in hydrogen service.

● **4.8** In addition to the design operating condition(s), the purchaser shall specify all operating conditions that could impose significant thermal stresses on the plate-fin heat exchanger. For guidance on various operational conditions see A.2.3. This shall include any alternative operating cases, for example the following:

a) turn-down operation;
b) upset-operation cases;
c) stream’s flowing condition (temperature, pressure, flow rate or composition) might change or cease abruptly;
d) process controls philosophy being applied to the heat exchanger (as applicable).

4.9 Plate-fin heat exchangers shall comply with the requirements of ALPEMA Standards, unless otherwise specified within this standard.

5 Proposal Information Required

5.1 The vendor shall provide a completed datasheet, including materials of construction, principal fin types (e.g., per the ALPEMA Standards) and free flow areas, inlet/outlet distributor types, and generic description of two-phase distributors. An example of a suitable format is given in Annex C.

5.2 Based on the scope of supply of the vendor, the calculated pressure drops reported on the datasheet shall include all frictional and acceleration losses from the inlet connection to the outlet connection, including any losses associated with separator vessels, interconnecting piping, and inlet/outlet manifolds for multi-core exchangers.

5.3 The static head (gravitational) losses or gains shall be considered in the performance design of the heat exchanger. The allowable and calculated pressure drop, however, shall consider only the frictional and acceleration losses.

● **5.4** When specified by the purchaser, the static head losses or gains shall be reported for information.

5.5 The first-time use by the vendor of a new technology, design, component, or material shall be clearly indicated by the vendor. See A.3.1 for additional guidance.

5.6 The vendor shall provide recommended strainer (size of mesh) requirements for each stream. See A.3.2 for additional guidance.

5.7 For block-in-shell heat exchangers, the vendor's proposal shall indicate the overall shell dimensions (diameter and length), the design liquid entrainment for the shell exit vapor stream (mass of liquid/mass of vapor), and a general description of any two-phase separation devices to be provided (e.g., de-misting pads). See Annex D for additional information on block-in-shell heat exchangers.

5.8 If a mercury-tolerant design is specified by the purchaser, the vendor shall provide a general description of the special design, manufacturing techniques, and procedures that are to be provided.

6 Drawings and Other Required Data

6.1 Outline Drawings and Other Supporting Data

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

a) Service(s), item number(s), project name and location, vendor's shop order number, and purchaser's order number;

b) maximum allowable working pressure, design pressure (including vacuum, if applicable), test pressure, maximum design temperature, minimum design metal temperature, and any restrictions regarding testing or operation of the plate-fin heat exchanger;

c) dimensions and location of supports, including bolt holes and slots, along with reaction loads at each point of support;

d) overall heat exchanger dimensions;

e) principal fin type(s);

f) presence and location of any inactive areas;

g) mass of the heat exchanger, both empty and full of liquid, with a specific gravity of 1.0;

h) center of gravity of the heat exchanger for empty and operating conditions;

i) material specifications for all components;

j) allowable forces and moments on connections at the header-to-nozzle joint;

k) connection sizes, location, orientation, projection, direction of flow, and, if flanged, the rating and facing or, if welded to the connecting piping, the thickness and weld bevel preparation;

l) insulation thickness (when specified by the purchaser);

m) location and orientation of nameplates, lifting devices, electrical grounding lugs, and other attachments as required;

n) recommended liquid levels (normal, minimum, and maximum operating liquid levels) for block-in-shell heat exchangers;

o) transition joint dimensions and any requirements and instructions for installation; and

p) references to the applicable code and purchaser's specification.

6.1.2 Bolting procedures including required torquing/tensioning values shall be provided for aluminum or non-standard flanges.

● **6.1.3** If specified by the purchaser, the vendor shall furnish the information necessary to allow the performance of the plate-fin heat exchanger to be modeled using commercially available software. The information provided shall include a stacking sequence or arrangement; dimensional details for each layer, including distributor type and dimensions; identification of fin(s) used; and fin geometry data, including type, height, thickness, fin pitch, fin perforation percentage/serration, length/crest distance (as applicable), and parting sheet thickness.

6.2 Information Required After Outline Drawings Are Reviewed

6.2.1 Upon receipt of the purchaser's review comments on the outline drawings, the vendor shall furnish detail drawings for the purchaser's review, including header fabrication, header internals for two-phase mixing, connection details, piping fabrication details, and separator vessel details (when provided by the vendor for two-phase distribution purposes). Detailed fabrication drawings for the block including details of proprietary in-layer two-phase devices need not be provided. The information provided shall include the following:

a) full views and cross-sectional views with all dimensions and materials sufficient for stress calculations for each part;

b) details of each pressure-retaining weld, including weld material, weld nominal thickness, weld location, and applicable nondestructive examination method;

c) details of each weld and weld nominal thickness for non-pressure attachments welded to pressure parts and for all load-bearing attachments;

d) complete bills of materials, including the materials specification; and

e) special installation and maintenance instructions, including lifting and handling.

● **6.2.2** If specified by the purchaser, the vendor shall furnish copies of applicable welding procedure specifications, procedure qualification reports, and weld maps for review or record.

● **6.2.3** If specified by the purchaser, the vendor shall furnish the following calculations for review or record:

a) pressure design code calculations, which shall include the following as a minimum:

   1) header, nozzle, and piping thickness calculations;

   2) shell calculations for block-in-shell heat exchangers;

   3) aluminum flange thickness calculations for flanges not within the scope of ASME B31.3, See Appendix titled "Aluminum Alloy Pipe Flanges";

   4) dissimilar flange material joint analysis (e.g. stainless steel or low-temperature carbon steel to

aluminum), when applicable (see 7.8.9);

    5) nozzle reinforcement calculations; and
    6) documentation certifying fin strength compliance to the applicable pressure design code. This can be in the form of certified proof test data, calculations, or a statement of compliance.

b) support calculations, including loads imposed by wind, seismic, and transportation conditions;

c) lifting device calculations;

d) transition joint calculations, or other documentation acceptable to the purchaser, to demonstrate the adequacy of the joint;

e) nozzle load calculations;

f) internal piping stress calculations for block-in-shell heat exchangers;

g) entrainment calculations used to size the shell for block-in-shell heat exchangers.

6.2.4 If cyclic service has been specified by the purchaser, the ability of the plate-fin heat exchanger to withstand the operation shall be demonstrated. The method of analysis to be provided and the requirements for review shall be agreed with the purchaser.

● **6.2.5** If specified by the purchaser, the vendor shall furnish procedures for pressure and leak testing and drying for review.

● **6.2.6** If specified by the purchaser, the vendor shall furnish an inspection and test plan.

6.3 Reports and Records

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

a) the final data sheets;

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

c) all mechanical design calculations, marked “CERTIFIED FINAL”;

d) certified mill test reports for all pressure parts;

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

f) third-party verification and certification when applicable;

g) nonconformance reports and resolutions;

h) nameplate rubbing or facsimile;

i) nondestructive examination map;

j) all associated nondestructive examination reports, including radiographic, magnetic-particle, liquid penetrant, ultrasonic, positive material identification (PMI), and any other reports as applicable;

k) pressure test records or report;

l) leak test records or report; and

m) the user's manual, containing:

   1) technical description;

   2) operating instructions (including any startup or shutdown constraints); and

   3) installation and maintenance instructions (including lifting and handling).

7 Design

7.1 General

The design of the plate-fin heat exchanger, including the suitability of the fins and the block to contain the pressure loadings, shall be in accordance with the pressure design code.

7.2 Design Temperature

● Each plate-fin heat exchanger shall only have two design temperatures, a maximum design temperature and a minimum design metal temperature (MDMT), as specified by the purchaser.

7.3 Design Pressure

● **7.3.1** The purchaser shall specify the design pressure for each stream, including any vacuum condition to be applied. When the plate-fin heat exchanger is to be installed within a pressure vessel, the purchaser shall also specify the design pressure of the pressure vessel, including vacuum rating.

7.3.2 Each stream of the plate-fin heat exchanger shall be designed for its independent pressure, with coincident atmospheric (or vacuum, if specified) on adjacent streams, as well as any pressure forces from the environment around the heat exchanger as applicable.

7.4 Thermal Stress

7.4.1 The design of the plate-fin heat exchanger shall be suitable for the design operating condition(s) and any other conditions identified by the purchaser that could impose significant thermal stresses on the heat exchanger. This shall include startup, shutdown, and turndown conditions, as well as any upset conditions (e.g., sudden changes in stream conditions, loss of process or utility stream flows, emergency shutdown (ESD) operation) and any cyclic temperature conditions specified by the purchaser.

7.4.2 The plate-fin heat exchanger shall be designed to accommodate stream temperature fluctuations of ±1 °C (±1.8 °F) per minute for each stream that may occur under otherwise steady-state operation.

7.4.3 The plate-fin heat exchanger shall be designed for the following maximum temperature differences between streams at any point in the heat exchanger: (See A.2.3 for additional guidance)

a) 50 °C (90 °F) for single-phase streams with steady-state operating conditions; and

b) 30 °C (54 °F) for two-phase streams or those with transient or cyclic operating conditions.

7.4.4 The plate-fin heat exchanger shall be designed to withstand a stream temperature rate of change of 5 °C/min (9 °F/min) as a minimum, not to exceed 60 °C (108 °F) in an hour for each stream for transient changes between two operating cases, including startup and shutdown operations. See A.4.1 for additional guidance.

7.4.5 When operating conditions exist that can subject a plate-fin heat exchanger to thermal transients, thermal gradients, or cyclic conditions in excess of those described in 7.4.4, a rigorous stress analysis and cumulative fatigue damage study may be necessary in order to estimate the impact of these events on the design life of the heat exchanger. The need for such analysis, the method of analysis, and the operating conditions to be considered shall be agreed between the purchaser and the vendor. See A.4.1 for additional guidance.

7.5 Thermal Design Margin

A heat transfer coefficient multiplier of 0.91 shall be used in thermal design of the heat exchanger unless otherwise specified by the purchaser.

NOTE 1 Plate-fin heat exchangers are typically only suitable for clean services. Fouling resistances should not be applied to this type of equipment.

NOTE 2A 0.91 heat transfer coefficient multiple is equivalent to a 10 % overall thermal design margin.
NOTE 3 The thermal design margin is in addition to any process margin specified on flow or duty.

7.6 Corrosion Allowance

The corrosion allowance shall be zero for aluminum and stainless-steel components. For other materials, the corrosion allowance shall be specified by the purchaser. See A.4.2 for additional guidance.

7.7 Supports

7.7.1 The plate-fin heat exchanger shall be provided with either lug supports or legs for installation on the purchaser's structure or foundation. The supports shall be designed for all the applicable loads, including wind and earthquake loads (when specified) and piping reaction loads.

7.7.2 Unless otherwise specified by the purchaser, the plate-fin heat exchanger supports shall be designed for an additional vertical load equal to the heat exchanger's dead weight, or 9070 kg (20,000 lbs), whichever is less, to account for external piping loads.

7.7.3 The vendor shall determine the minimum operating temperature at the mounting support.

a) This temperature shall be indicated on the outline drawing when support beams are provided by others.

b) When support beams are in the vendor's scope, the vendor shall determine the need for heat break insulation devices between the plate-fin heat exchanger support and support beams. If insulation devices are needed, they shall be provided by the vendor with the support beams.

7.7.4 The supports shall be provided with holes/slots for the installation of mounting bolts and shall allow for the contraction/expansion of the plate-fin heat exchanger in accordance with the ALPEMA Standards. The slots shall be applied prior to shipment, unless otherwise agreed.

● **7.7.5** If specified by the purchaser, the supports shall have an electrical grounding lug or boss.

7.8 Connections

7.8.1 When a mercury-tolerant design has been specified, all plate-fin heat exchangers, assemblies, manifolds, and piping shall be self-draining through the process connections for the identified streams.

● **7.8.2** If specified by the purchaser, the plate-fin heat exchanger, assemblies, and manifolds shall be self-draining and self-venting through the process connections for all pass arrangements.

● **7.8.3** For block-in-shell heat exchangers, the projection of flanged connections shall allow for through-bolting to be removed from either side of the flange without removing the insulation. The insulation thickness shall be specified by the purchaser.

7.8.4 All bolt holes for flanged connections shall straddle centerlines.

7.8.5 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.

7.8.6 Flanged connections shall be weld-neck type.

7.8.7 Nozzles smaller than DN 300 (NPS 12) shall be manufactured from seamless pipe, unless otherwise approved by the purchaser. Where fabricated pipe from rolled and welded plate is used, the longitudinal weld seam shall be 100 % examined by radiographic or ultrasonic methods.

7.8.8 Where aluminum alloy flanges are to be connected to aluminum piping flanges, the thickness shall not be less than the mating flange thickness and the flanges shall be compatible in terms of dimensions, drilling, and flange facing. The mating flange thickness shall be provided by the purchaser.

7.8.9 Where aluminum alloy flanges are to be connected to piping that uses a dissimilar flange material (e.g., stainless steel or low-temperature carbon steel), the vendor shall perform calculations that prove the adequacy of aluminum alloy pipe flanges, considering the mating flange material, bolting, and gasket materials, as specified by the purchaser. The method of analysis and conditions, including transients, to be evaluated shall be agreed between the vendor and the purchaser. See A.4.3 for additional guidance.

7.8.10 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.

7.8.11 Unpressurized inactive areas in plate-fin heat exchangers, shall be provided with vent and drain holes that are to be sealed by a shipping plug during shipping, handling, and storage. Examples of inactive areas include: dummy layers, spaces formed by welding two or more blocks, spaces formed between two streams in the same layer with adjacent side headers. The shipping plugs shall be removed or replaced with vent lines or equivalent after installation, as instructed by the vendor. See A.4.4 for additional guidance.

7.8.12 Unless otherwise specified by the purchaser, each header and header attachment to the block shall be capable of withstanding the simultaneous applications of the piping resultant moments and forces as defined in the “Nozzle Loadings” section of ALPEMA Standards. See A.4.5 for additional guidance.

7.8.13 Limits of reinforcement for designs that are common in plate-fin heat exchanger fabrication (i.e., tangential nozzles), but that are not specifically addressed in the pressure design code, shall be based on alternate methods of analysis as agreed between the vendor and the purchaser.

7.9 Bimetallic Transition Joints

7.9.1 Bimetallic aluminum-to-stainless steel piping transition joints shall be designed in accordance with ASME B31.3 Paragraph 304.7.2 for unlisted components. The acceptance of designs based on ASME B31.3, Paragraph 304.7.2.a shall not be used. For designs qualified by ASME B31.3, Paragraph 304.7.2.b or d, interpolation as allowed by ASME B31.3, Paragraph 304.7.2.e shall not be used.

7.9.2 The design of the transition joint shall be demonstrated to have a pressure and load-bearing capability equivalent to or exceeding the weaker of the two materials joined. In designs where the transition joint has a lower load-bearing capability than the weaker of the two materials, the vendor shall indicate this joint as the limiting component in the pressure design code documentation and provide the load-bearing limit.

7.9.3 Transition joints shall be qualified by the following tests prior to their first use. Prototype testing of duplicate or geometrically similar parts to establish maximum allowable working pressure by proof test, as defined, as defined in ASME *BPVC*, Section VIII, Div. 1, may be used. Any deviations in the design, as prescribed ASME *BPVC*, Section VIII, Div. 1, shall require the qualification of an additional prototype.

a) A thermal cycle test shall be performed prior to any other applied tests. Three thermal cycles shall be applied unless additional cycles are specified by the purchaser. A single thermal cycle shall consist of the following steps:

    1) Immerse the component in water and bring to a temperature of no less than 80 °C (180 °F).

2) Immerse the component in liquid nitrogen and bring to the temperature of the nitrogen.

3) Re-immerse the component in water and bring to a temperature of no less than 80 °C (180 °F).

b) A helium vacuum leak test shall be performed. For transition joints less than or equal to DN 150 (6 NPS), the allowable leakage rate shall be 1 x 10-8 atm-cc/sec. For larger sizes, the allowable leakage rate shall be 1 x 10-7 atm-cc/sec.

7.9.4 The transition joint shall have the same inside diameter throughout the length over which the material transition is achieved. If necessary, an internal taper bore shall be provided at the terminal ends of the transition joint to match the wall thickness of the connecting piping.

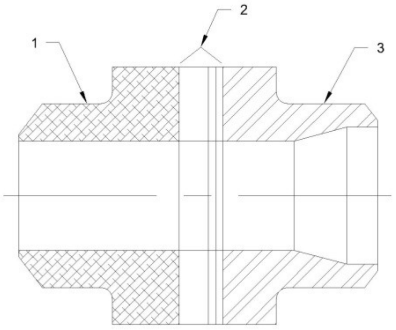
7.9.5 The transition joint manufacturer shall specify the maximum temperature conditions that shall not be exceeded during the installation of the transition joint to the plate-fin heat exchanger and piping. The temperature shall be monitored during the installation. If temperature-indicating strips are used, they shall not be removed until after the verification of any indications.

7.9.6 Transition joints shall be one of the following types (see Figure 3). Other types may be used when approved by the purchaser.

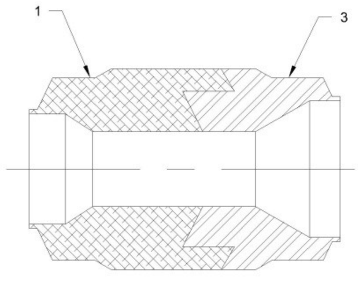
a) parallel plate explosion welded (sometimes referred to as explosion bonded) type (Type 1);

b) interference fit type (Type 2);

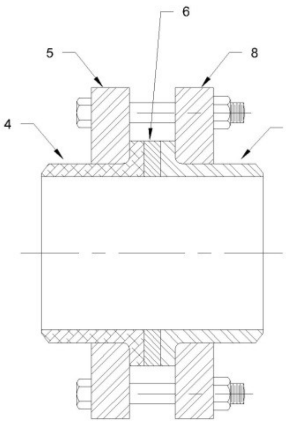
c) flanged reinforced type (Type 3).



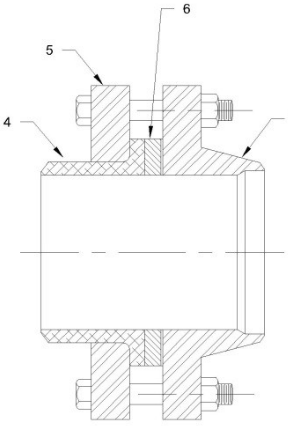
Type 1—Explosion Welding



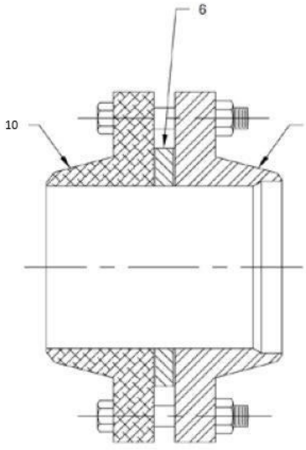
Type 2—Interference Fit



Type 3A—Flange Reinforced



Type 3B—Flange Reinforced



Type 3C—Flange Reinforced

Key:

1	Aluminum butt welding end
2	Interlayers of dissimilar metallurgy
3	Stainless steel butt welding end
4	Aluminum stub end
5	Stainless steel lap joint flange
6	Bimetallic clad ring
7	Stainless weld neck flange
8	Stainless steel lap joint flange
9	Stainless steel stub end
10	Aluminum weld neck flange

Figure 3—Bimetallic Transition Joints

7.9.7 Type 1 transition joints consist of parallel plate or sheets of dissimilar metallurgy that are explosion welded to produce a butt-joint transition between the two base metals.

7.9.8 Type 2 transition joints shall consist of aluminum and stainless steel transition pipes that are attached to machined forgings or bars designed for an interference fit. These joints are then assembled to produce an interference fit within the machined ends.

7.9.9 Type 3 transition joints may consist of the following sub-types:

a) Type 3A, consisting of the following:

   1) aluminum lap-joint stub end in accordance with ASME B16.9;
   2) stainless steel lap joint stub end in accordance with ASME B16.9;
   3) two stainless steel lap joint flanges in accordance with ASME B16.5/ASME B16.47;
   4) a bimetallic transition ring made of a clad or “bimetal” aluminum and stainless steel composition installed between the faces of the stub ends, and continuously seal welded; and
   5) strain-hardened stainless steel bolts and nuts joining the flanges and tack welded in place after tightening.

b) Type 3B, consisting of the following:
   1) aluminum lap joint stub end in accordance with ASME B16.9;
   2) stainless steel welding neck flange in accordance with ASME B 16.5/ASME B16.47;
   3) stainless steel lap joint flange in accordance with ASME B16.5/ASME B16.47;
   4) a bimetallic transition ring made of a clad or “bimetal” aluminum and stainless steel composition installed between the faces of the stub end and the welding neck flange and continuously seal welded; and
   5) strain-hardened stainless steel bolts and nuts joining the flanges and tack welded in place after tightening.

c) Type 3C, consisting of the following:
   1) aluminum weld neck flange in accordance with ASME B16.5;
   2) stainless steel welding neck flange in accordance with ASME B 16.5;
   3) a bimetallic transition ring made of a clad or “bimetal” aluminum and stainless steel composition installed between the faces of the welding neck flanges and continuously seal welded; and
   4) strain-hardened stainless steel bolts and nuts joining the flanges and tack welded in place after tightening.

7.10 Temperature and Pressure Monitoring

● **7.10.1** When specified by the purchaser, the vendor shall provide suitable fluid or metal temperature-indicating devices at locations on the plate-fin heat exchanger to allow the operator to measure and monitor cool-down and warm-up rates. The quantity, type, and location of such devices shall be agreed between the vendor and the purchaser.

● **7.10.2** When specified by the purchaser, the vendor shall provide connections for differential pressure monitoring devices across boiling passages for the purpose of detecting unstable flow conditions. The type and location of such connections shall be agreed between the vendor and the purchaser. See A.2.3.6 for additional guidance.

7.11 Handling Devices

The plate-fin heat exchanger shall be provided with suitable lifting lugs, trunnions, or similar devices. The lifting device shall be welded to the heat exchanger. Lifting lug holes (when provided) shall be not less than 38 mm (1$^1/_2$ in.) in diameter. The design of the lifting device shall be based on twice the empty mass of the heat exchanger.

8 Materials

8.1 The vendor shall recommend materials, including aluminum alloy grades and temper conditions, based upon their brazeability, weldability, and suitability for the process service for the approval of the purchaser. See A.5 for additional guidance.

8.2 When the presence of mercury, organo-mercuric compounds, heavy metals, or water has been identified, the vendor shall consider this in the recommendation of materials. See A.2.2 for additional guidance.

8.3 When mercury tolerant design has been specified, the magnesium content of aluminum backing strips shall be less than 0.20%.

8.4 The nameplate shall be of corrosion-resistant material, such as an aluminum alloy or austenitic stainless steel.

8.5 Material for external parts that are welded directly to the plate-fin heat exchanger, such as pads, brackets, and lugs, shall be of the same nominal composition as the material to which they are welded.

NOTE All aluminum alloys are considered to be same nominal composition.

9 Fabrication

9.1 Welding and Brazing

9.1.1 All pressure-containing welding and brazing, including welds attaching components to the pressure boundary, 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.

9.1.2 All pressure-containing welds, except side bar joints, shall be full penetration and full fusion unless otherwise approved by the purchaser.

9.1.3 Butt-welded joints and header to block welds shall achieve complete penetration and full fusion.

9.1.4 After arc, flame, or similar nonmechanical cutting, all fused metal and metal whose mechanical or chemical properties may have been altered by the cutting process shall be removed by mechanical means.

9.1.5 The oxygen arc method shall not be used to cut aluminum materials.

9.1.6 The use of backing strips shall be in accordance with the following:

a) For mercury tolerant designs,

    1) backing strips that are accessible after welding shall be removed.

    2) For backing strips that are not accessible for removal, the backing strips shall be installed by seal welding on the upstream flow side for horizontal flow arrangements and on the upper side of vertical flow arrangements, regardless of the flow direction to promote free draining.

b) For other services, the backing strips may remain in place permanently, unless the purchaser specifies that backing strips shall be removed after welding (if accessible).

c) The use of consumable inserts or backing strips may be used when approved by the purchaser. See A.6 for additional guidance.

9.1.7 The requirements for welding within this standard shall apply to all welds on pressure parts, including permanent and temporary attachments.

9.1.8 Temporary attachments or arc strikes on the pressure parts shall be avoided as far as practical. If they occur, they shall be removed, and the surface shall be properly conditioned to eliminate surface stress risers.

9.1.9 Welding of aluminum shall be performed using gas tungsten arc or gas metal arc welding.

9.2 Reinforcing Pads and Wear Plates

9.2.1 All reinforcing pads shall be continuously welded and have one 6 mm ($^1/_4$ in.) tapped hole in each segment for venting. Vent holes shall be filled with a grease suitable for cryogenic applications, after testing.

9.2.2 Reinforcing pads shall not be used on streams that are in hydrogen or cyclic service.

9.2.3 If wear plates are continuously welded, they shall have one 6 mm ($^1/_4$ in.) tapped hole in each segment for venting. Vent holes shall be plugged with a plastic plug or equivalent after testing.

9.3 Dimensional Tolerances

The standard tolerances for the external dimensions of plate-fin heat exchangers and manifolded assembly of multiple blocks shall be in accordance with the ALPEMA Standards.

9.4 Concavity

9.4.1 Cap sheets can be slightly concave and shall be checked after brazing but prior to the installation of any headers.

9.4.2 Concavity, defined as the deviation from a plane, shall be measured across the width of the core at different positions along its length with a maximum interval of 1 m (3 ft) intervals, and a minimum of 3 equally spaced measurements.

9.4.3 Concavity shall not exceed either 3 mm (1/8 in.) or the value determined from the following, whichever is greater:

$$\text{Maximum concavity} = (0.0057 \times W) + (0.003 \times L)$$

where W is the nominal width of the core and L is the nominal length of the core, in either mm or inches.

NOTE 1: This formula is independent of units provided that a consistent set of units are applied.
NOTE 2: This formula does not apply to cores whose heights (H) exceed three times their width (W). For such cases the maximum concavity is to be agreed upon by the purchaser and the manufacturer.

10 Inspection and Testing

10.1 Quality Control

● **10.1.1** If specified by the purchaser, after completion of the brazing, the supplier shall provide a certificate confirming that the internal production parameters and quality procedures have been followed in brazing process.

10.1.2 Weld inspection requirements shall be as follows.

a) All accessible butt welds shall be spot radiographed as a minimum (see A.7.1 for additional guidance).

b) Spot radiographs shall include each start and stop of welds made by the automatic welding process.

c) Spot radiographs shall be at least 250 mm (10 in.) long or shall be full length if the weld is less than 250 mm (10 in.) long.

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

e) 100 % radiographic examination shall be performed on any welded seam of a component in a fabricated header that has been subjected to severe working after welding, i.e., where the ratio of thickness to local radius, is greater than 5 %.

f) On pressure parts, all attachment welds (fillet, structural attachment, lug, etc.) with a throat greater than 6 mm ($^1/_4$ in.) and all lifting lug attachments shall be examined and evaluated by the liquid penetrant method in accordance with the pressure design code. Any surface irregularities that interfere with the examination shall be removed by grinding or machining. Indications from an adjacent brazed fusion line may be ignored.

10.1.3 Completed welds on the headers and any piping, including the header-to-block weld and connections to the headers which have not been volumetrically examined, shall be examined by the liquid penetrant method. The acceptance criteria shall comply with the pressure design code.

10.1.4 The inspection and testing of bimetallic transition joints shall comply with the following:

a) Type 1 transition joints shall be provided with the following inspection and testing.

   1) Fabrication and testing shall conform with ASME *BPVC*, Section VIII, Division 1, Code Case 2493, including the requirements for weld procedure and weld operator performance qualifications, and production welding examination and testing requirements.

   2) Each individual explosion weld interface shall be subject to ultrasonic examination prior to the explosion welding of the next layer.

   3) The completed transition joint shall have its edges dye-penetrant examined on both the inside and outside surfaces. The acceptance criteria shall be as per the pressure design code.

   4) The completed transition joint shall be subject to visual and dimensional inspection.

   5) Each completed transition joint shall be helium leak tested. The acceptance criteria shall be as required by 7.9.3.b.

b) Type 2 transition joints shall be provided with the following inspection and testing.

   1) The completed transition joint shall be subject to visual and dimensional inspection.

   2) The completed transition joint shall be helium leak tested. The acceptance criteria shall be as required by 7.9.3.b.

   3) Each completed transition joint shall be hydrostatically tested in accordance with the applicable pressure design code.

c) Type 3 transition joints shall be provided with the following inspection and testing.

   1) The parent clad plate from which the bimetallic seal ring is provided shall be subjected to shear testing to verify the bond strength. The minimum shear strength of the cladding and base metal shall not be less than 8000 psi at room temperature. The method for shear testing shall be as agreed between the manufacturer and purchaser.

   2) The parent clad plate shall be tested to determine the maximum compressive load that can be applied without permanent set. This maximum load shall be greater than the bolting or service loads to be applied.

   3) Each clad bimetallic seal ring shall be 100 % ultrasonically examined. There shall be no single unbonded area exceeding 5 mm ($^3/_{16}$ in.) in its longest dimension, with the total unbonded area not to exceed 1 % of the total cladded surface area.

   4) Each clad bimetallic seal ring shall have its edges dye-penetrant examined on both the inside and outside surfaces. The acceptance criteria shall be as per the pressure design code.

   5) All welds, including seal welds of the seal ring to the flange(s), but excluding tack welds securing the nuts to the studs, shall be dye-penetrant examined. The acceptance criteria shall be as per the pressure design code.

6) The completed transition joint shall be subject to visual and dimensional inspection.

7) Each completed transition joint shall be helium leak tested. The acceptance criteria shall be as required by 7.9.3.b.

● **10.1.5** When specified by the purchaser, a sacrificial mockup transition joint from same manufacturing run as the production transition joint shall be subjected to thermal cycle testing followed by a helium leak test. The scope and quantity of mockup test shall be agreed upon between the purchaser and the vendor. Unless otherwise specified, the definition of and number of cycles to be applied shall be as required by 7.9.3.a. See A.7.2 for additional guidance.

10.2 Pressure and Leak Testing

10.2.1 Prior to the code pressure test, a low-pressure leak test shall be performed with either dry air or nitrogen at a gauge pressure of 200 kPa (30 psig). Each chamber shall be tested individually, using a soap-water solution to show leaks. An alternate method of testing may be used if approved by the purchaser.

10.2.2 Plate-fin heat exchangers shall be pressure tested in accordance with the pressure design code.

10.2.3 The pressure test may be either a hydrostatic or pneumatic test at the discretion of the vendor and shall be subject to the agreement of the purchaser.

10.2.4 Each chamber shall be individually tested without pressure in adjacent chambers.

10.2.5 For hydrostatic code pressure tests, the test pressure shall be maintained for a minimum of 30 minutes. For pneumatic code pressure tests, the test pressure shall be maintained for a minimum of 10 minutes.

10.2.6 For each pressure test, two indicating gauges (or one indicating gauge and one recording gauge) shall be attached to the plate-fin heat exchanger.

10.2.7 The water used for hydrostatic testing shall be potable.

10.2.8 The chloride content of the test water used for equipment with austenitic stainless steel components that would be exposed to the test fluid shall not exceed 50 mg/kg (50 parts per million by mass).

10.2.9 Upon completion of the hydrostatic test, the vendor shall ensure that the plate-fin heat exchanger is thoroughly dried prior to any subsequent leak testing and shipment.

10.2.10 Each segment of each reinforcing pad and wear plate shall be tested with dry air or nitrogen, at a gauge pressure of 100 kPa (15 psig).

● **10.2.11** When specified by the purchaser, external and inter-stream helium leak tests shall be conducted in accordance with the ALPEMA Standards.

● **10.2.12** When more stringent inter-stream leak tightness than required by the ALPEMA Standards is necessary (e.g., due to product purity consequences), acceptable leakage rates shall be agreed between the purchaser and the vendor.

10.3 Rectification

10.3.1 Weld repairs to side brazed joint separations, corner bar joints, and side bar joints that are made prior to the completed pressure test may be made by the vendor without prior notification, unless otherwise specified by the purchaser.

10.3.2 Weld repairs to pressure-retaining welds on headers, nozzle assemblies, nozzle-to-header attachments, and header-to-core attachment welds made prior to the completed pressure test shall be made only after the notification of the purchaser unless such repairs are:

a) less than 10 mm ($^3/_8$ in.) in depth or half of the weld thickness, whichever is less, or;

b) less than 50 mm (2 in.) in length or 20 % of the total weld length, whichever is less.

10.3.3 A second weld repair to a weld which required a notification per Clause 103.2. shall only be made after the approval from the purchaser.

10.3.4 All pressure-retaining weld repairs that are required after the completed pressure test shall only be performed after the notification and approval of the purchaser.

10.3.5 Weld repairs shall only be made using approved procedures and shall be re-examined for defects in accordance with the original quality control requirements for the weld.

10.3.6 Documentation related to all weld repairs, including re-examination reports, shall be retained and made available to the purchaser.

10.3.7 If defect rectification requires the blocking of one or more active layers,, the vendor shall supply calculations that confirm the adequacy of the unit for the originally specified service, including the required thermal and hydraulic performance and mechanical integrity. The results shall be treated as follows:

a) If calculations demonstrate that required thermal and hydraulic performance and mechanical integrity are met, vendor shall notify the purchaser prior to performing any work.

b) If calculations demonstrate that required thermal and hydraulic performance and mechanical integrity are not met, vendor shall notify the purchaser and obtain purchaser’s approval prior to performing any work.

10.3.8 Repairs to the plate-fin heat exchanger resulting from other damage (e.g., improper handling, etc.) that may affect the pressure retention and/or structural integrity of the heat exchanger shall only be made after the proper notification and approval of the purchaser.

10.4 Nameplate

10.4.1 A nameplate shall conform to the requirements of the ALPEMA Standards.

10.4.2 The nameplate shall be readily accessible after the installation, including insulation, of the plate-fin heat exchanger. A duplicate nameplate may be provided for this purpose when the pressure design code nameplate is not readily accessible.

10.4.3 In addition to the information required by pressure design code on nameplate, purchaser’s item number shall also be included.

11 Preparation for Shipment

11.1 Preparation for shipment shall be in accordance with the ALPEMA Standards, and the additional requirements of this standard.

11.2 Where stub-end connections are provided, the vendor shall provide a weld cap or shipping disk of suitable material on the nozzle assembly in order to protect and seal the connection for shipment. The connection shall be provided with sufficient excess length to allow for beveling of the connection (by others) at the installation site after the removal of the shipping cap or disk.

11.3 Each stream shall be provided with a shipping pressure gauge and valve. These are to be removed just prior to installation.

11.4 Any temporary devices provided for shipping that need to be removed prior to commissioning such as shipping plugs, shall have a contrasting color and be identified for removal in accordance with vendor’s installation instruction.

Annex A

(Informative)

Recommended Practice

A.1 Introduction

This annex has been prepared to give advice to the designer. The advice is not mandatory and is offered for guidance only.

In this annex, the numbers in parentheses after the section headings correspond to those in the main body for that subject but are prefixed by the letters “RP.”

A.2 General Requirements

A.2.1 Cyclic Design—Guidance to 4.4 and 4.6

A.2.1.1 Pressure design codes will generally require that a fatigue evaluation be performed for any service which has been designated to be cyclic. These codes normally provide requirements related to the magnitude of pressure and thermal fluctuations which need to be considered as part of the evaluation.

A.2.1.2 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 (Part 3).

A.2.1.3 Pressure design codes including ASME BPVC, Section VIII, Division 2 and EN 13445 (Part 3) provide screening methods to determine if a fatigue analysis is required for the given cyclic loading. If required, rules for performing a full fatigue analysis are included. Other methods of screening and evaluation of fatigue analysis may be used based on agreement between the purchaser and the vendor.

A.2.2 Mercury Contamination—Guidance to 4.5

A.2.2.1 The presence of mercury in process or utility streams can lead to corrosion and failure of plate-fin heat exchangers through either liquid metal embrittlement or amalgam corrosion mechanisms. Refer to the ALPEMA Standards for further information.

A.2.2.2 When the potential exists for streams to contain mercury, mercury guard beds and dehydration equipment should be used upstream of the heat exchangers. Guard beds are typically designed to achieve a maximum mercury concentration of 0.01 μg/Nm^3. See the ALPEMA Standards for additional guidance.

A.2.2.3 Mercury-tolerant plate-fin heat exchanger design features should be provided whenever the streams may contain mercury in any amount, including those applications for which a guard bed has been installed.

A.2.3 Operating Conditions —Guidance to 4.8

Following considerations should be taken into account when specifying various operating conditions, design, fabrication and operation of the plate-fin heat exchanger.

A.2.3.1 Freeze Rupture

Proper dehydration equipment must be installed upstream of brazed aluminum plate-fin heat exchangers to avoid condensing and freezing of free water, as ice formation inside plate-fin exchangers can result in mechanical damage. Hydrotesting of plate-fin heat exchangers in the field is not recommended. If the decision is made to hydrotest a plate-fin heat exchanger in the field, extreme caution must be exercised as the compact arrangement of internal heat transfer fins makes it extremely difficult to completely remove water after the completion of the hydrotest. Failure to completely remove water following a field hydrotest may result in ice formation inside the heat exchanger, which may lead to mechanical damage, including bursting failure. It is recommended that the plate-fin heat exchanger be adequately dried following a field hydrotest, to completely displace all free water prior to placing the heat exchanger back in service. Methanol soaking or the circulation of a warm [65 °C (150 °F)], dry nitrogen stream for a sufficient period of time have been used to dry heat exchangers after a field test.

A.2.3.2 Thermal Cycling

Aluminum has no endurance limit, which is defined as the mechanical stress below which a material has infinite cycle life. As such, any thermal cycling events will reduce the life span of the plate-fin heat exchanger block and must be minimized.

A.2.3.3 Pressure Cycling

Analogous to thermal cycling, pressure cycling can also be detrimental to plate-fin exchangers if they have not been designed for this condition. Initiating repeated pressure cycles can cause the parting sheets to be exposed to frequent pressure inversions and displacements (“oil canning”), resulting in excessive cold work and fatigue to these pressure-retaining components of the heat exchanger.

A.2.3.4 Excessive Thermal Differentials

During plate-fin heat exchanger startup and operation, great care must be taken to ensure adjacent stream temperature differentials do not exceed the design limits. Failure to maintain adjacent stream temperature limits can result in excessive stresses and heat exchanger failure.

A.2.3.5 Excessive Thermal Transients

Excessive thermal transients may result in fatigue failure of the plate-fin heat exchanger. This may manifest as external leaks due to separation between the parting sheets and the side bars around the periphery of the heat exchanger, or may result in inter-pass leaks between streams where the parting sheets fail within the confines of the heat exchanger.

A.2.3.6 Two-Phase Flow Instability

A.2.3.6.1 Boiling passes in plate-fin heat exchangers, in either forced flow or thermosiphon service, can be subject to two-phase flow instability. Low pressure systems, streams which are two-phase at the inlet to the heat exchanger, and streams which are fully vaporized within a passage are of particular concern. The potential for unstable flow often limits the turndown capability in such systems.

A.2.3.6.2 Unstable flow can result in the heat exchanger being unable to reach its required heat transfer duty. Depending on its severity and the local temperature differences, unstable flow can also subject the exchanger to significant **transient** thermal stresses which can lead to thermal fatigue damage if operation under such conditions is allowed to continue.

A.2.3.6.3 The potential for unstable flow should be eliminated where possible through system design and the proper identification of acceptable integrity operating windows.

A.2.3.6.4 The presence of unstable flow may not be detectable through standard inlet and outlet stream temperature measurements or through the addition of skin temperature indication points. For boiling streams which may be **susceptible** to unstable flow, the installation of a differential pressure indication on the boiling pass, monitored for fluctuating pressure drop, can be more reliable for identifying when unstable flow may be occurring so that appropriate operator actions may be taken.

A.2.3.6.5 Refer to the ALPEMA Standards and GPA-TB-001 for additional guidance.

A.2.3.7 **Flow** Maldistribution

A.2.3.7.1 Uniform flow distribution, both to the individual passages and across the width of each passage, is critical to the proper performance of plate-fin heat exchangers due to their inherently high efficiency. Suitable design considerations can minimize the amount of maldistribution. These include the choice of the header type used, **the** choice of distributor type used, along with the dimensions of the distributor, the arrangement, and location of the headers (e.g., same versus opposite side locations), and the choice of both distributor and heat transfer finning types with respect to pressure drop utilization. See figures in ALPEMA standards for typical header types and distributor types. Most software tools used to model the performance of brazed aluminum plate-fin heat exchangers have the ability to assess the amount of maldistribution, as well as account for it in the performance design.

A.2.3.7.2 For streams that may contain water, the inlet and outlet distributors should be the type which do not contain no-flow regions to promote full drainage and flushing, particularly at the bottom end of the exchanger as installed. Distributor types including the "Re-entrant B" and "Diagonal C" (see the figure in ALPEMA Standards), are **examples** of distributors absent of no-flow regions and should be considered in these services.

A.2.3.7.3 Special attention is required for streams that are two-phase at the inlet to the plate-fin heat exchanger, particularly for **multicomponent** boiling applications. When flow maldistribution of liquid and vapor phases occur, the phases are no longer homogeneously mixed. Separation of phases can result in different heat transfer coefficients and stream temperatures within the same heat exchanger layers. Poor thermal performance and potentially different thermal expansion rates and high thermal stresses can result from two-phase flow maldistribution leading to heat exchanger failure if these are beyond the design limits. For some cases, depending upon the relative amounts of vapor and liquid to be distributed, the phases are first separated in a separation vessel, with the resulting phases introduced to the heat transfer passages through separate distributors or devices to achieve uniform distribution. See the figure (perforated tube or bar distributor) in ALPEMA Standards for typical devices that may be provided.

A.2.3.7.4 Plate-fin heat exchangers and their associated inlet flow distribution devices are generally designed for optimal operation at a single set of process conditions, while at the same time being suitable for other defined operating cases. When operating conditions fall outside the design envelope, such as during startup or turndown **conditions**, liquid and vapor phases may separate, and flow maldistribution may occur. Care must be exercised to define the acceptable operating window so as not to expose the plate-fin heat exchanger to detrimental thermal stress.

A.2.3.8 **Plate-fin** Heat **Exchanger Plugging**

A.2.3.8.1 Plate-fin heat exchanger flow passages are very small and susceptible to foreign material plugging. Typical foreign materials may include molecular sieve dust, mill scale in piping, and ethylene glycol from upstream dehydration units. Care must be taken when selecting upstream filtration devices for plate-fin heat exchangers, and it is typically recommended that 177-micron (80-Tyler) mesh screens be specified at a minimum. When **installing** a molecular sieve dehydration bed upstream of the heat exchanger, dust filters should be used to avoid mole sieve carryover, which can plug the heat exchanger inlet distributor fins. When installing a glycol dehydration unit upstream of a plate-fin heat exchanger, it is imperative to minimize glycol carryover since glycol can adhere to and easily foul a plate-fin heat exchanger.

A.2.3.8.2 Plugging can cause high-pressure drop in a plate-fin heat exchanger. If a stream becomes heavily plugged, it is possible that local velocities can be high enough to cause erosion of the thin fin material, which could lead to mechanical **problems** with the equipment. Nonuniform plugging can also result in local temperature differences in the heat exchanger, which can lead to detrimental thermal stresses. It is not recommended to operate a plate-fin heat exchanger in a highly plugged condition.

A.2.3.8.3 In the event that a plate-fin heat exchanger has become plugged, it may be necessary to back blow the unit to restore thermal-hydraulic performance. This is typically accomplished through the use of a rupture disk or quick-opening valve. In most cases, back blowing will only partially restore heat exchanger performance, hence the importance of **proper** upstream filtration. As an alternative to back blowing, soaking with liquid solvent (such as cyclohexane or methanol) may also be considered if the fouling or plugging medium is dissolved by these fluids or solvents.

A.2.3.9 Plate-fin Heat Exchanger Restart after Temporary Shutdown

A.2.3.9.1 It is quite **common** during temporary plant shutdowns for a restart to occur in a matter of minutes or hours.

A.2.3.9.2 A plate-fin heat exchanger restart after a temporary shutdown should be examined on a case-by-case basis. Some applications may require the complete removal of liquids prior to a restart, while other applications have been demonstrated to have the ability to restart with liquids in the heat exchanger with acceptable **levels** of thermally induced stresses. Still other processes may have a limited time period and/or set of conditions that should be met in order to restart without draining liquids from the heat exchanger.

A.2.3.9.3 In cases where the removal of liquids prior to a restart is necessary, the liquid should be removed in such a way as to minimize the temperature impact to the plate-fin heat exchanger. This may be done by closing valves on the flow lines to the nozzles on the top of the heat exchanger and draining the liquid from the bottom nozzles and through a blowdown valve located a minimum distance from the heat exchanger. Reducing the pressure of the liquid passages and exhausting these through the top nozzles can subject the heat exchanger to undesirable temperature differences.

A.2.3.9.4 Where liquid draining is required, the failure to do so can result in the entire plate-fin heat exchanger being reduced to the temperature of the cold liquid stream. Introducing a hot process stream into a plate-fin exchanger pre-cooled to cold liquid temperature can result in very high thermally induced stresses, leading to instantaneous failure in extreme cases.

A.2.3.10 External and Internal Leak Detection

A.2.3.10.1 An equipment monitoring program to check for external leaks from the heat exchanger or cold box should include:

a) Visually inspect the exterior of the cold box or exchanger in operation for ice-build up, frost spots, dripping fluids, and gas **clouds**. This may indicate external leaking is occurring, or there may be an insulation problem.
b) Hydrocarbon detection in the vicinity of the heat exchanger or cold box.
c) Consider installing inter-modular zone gas leak detection devices to monitor this space of modular cores which may be **particularly** prone to transient thermal stresses.
d) Infrared thermographic inspection.

A.2.3.10.2 **External** leaks can usually be repaired during plant shutdowns. Refer to the ALPEMA Standards and GPA-TB-001 for additional guidance.

A.2.3.10.3 Internal leaks will result in inter-pass leakage between higher- and lower-pressure streams. They can be identified by **sampling** the lower-pressure streams during normal operation or may be found by inter-stream leak testing during plant shutdowns.

A.2.3.10.4 Internal leaks are normally remedied by isolating and blocking the failed layer(s). The vendor should be consulted on all such decisions as the blocking of layers can change the thermal/hydraulic performance and may result in an unacceptable thermal profile or flow maldistribution. This will often require that an **additional** number of adjacent layers be blocked to prevent a significant thermal imbalance. Blockage of layers can result in increased thermal stresses and fatigue as compared to the heat exchanger's initial design condition, and this should be considered for future life assessments and replacement strategies.

A.2.3.10.5 When layers are blocked from the process stream, it is imperative that these be opened to the atmosphere so as not to create a pressurized space in a now inactive and compromised layer. Temporary plugs or caps that may have been placed over these openings must be removed prior to operation. The number and size of **openings** should be such that the passage would not become over-pressured based on the worst-case leak.

A.3 Proposal Information Required—Guidance to 5

A.3.1 First Time Use—Guidance to 5.5

Plate-fin 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., a newly developed fin type, material, or two-phase distribution system that had not been previously applied or would be applied to conditions outside of prior operating experience.

A.3.2 Strainers—Guidance to 5.6

The purchaser should install a strainer(s) upstream of the plate-fin heat exchanger. The recommended strainer mesh size is 177 µ (80 Tyler), unless the plate/fin gap design dictates that a finer mesh size be used. Typical particle sizes should be no larger than ½ of the minimum gap. Refer to GPA-TB-001 for additional guidance related to strainers.

A.4 Design

A.4.1 Thermal Stress—Guidance to 7.4.5

A.4.1.1 Plate-fin heat exchangers are relatively compact, rigid structures and are susceptible to damage if subjected to operating conditions that produce excessive thermal stresses. Thermal stress can result from the normal presence of streams at different temperatures, as well as stresses that develop due to transient and/or cyclic operating conditions. Modular cores can be more susceptible to thermal stress during transient conditions than single cores or manifolded batteries of multiple exchangers. Refer to the ALPEMA Standards for typical transient temperature limitations and operating recommendations for startup, shutdown, and other transient operation of plate-fin heat exchangers. Refer to the ALPEMA Standards for permissible steady-state temperature limits between streams.

A.4.1.2 Refer to the ALPEMA Standards for recommended good practices related to thermal stresses in the design and operation of plate-fin heat exchangers.

A.4.1.3 Operating outside the recommended limits of the ALPEMA Standards *for temperature difference between streams and temperature rate of change*, can impose stresses on the brazed aluminum plate-fin heat exchanger that may result in accelerated life consumption of the heat exchanger. The fatigue life of a plate-fin heat exchanger can be assessed through analysis, provided that adequate operating data is available.

A.4.1.4 Fatigue life or remaining fatigue life estimation requires detailed information on the number of thermal and/or pressure events that a plate-fin heat exchanger has been or will be subjected to, as well as the stress magnitudes that each event imposes on the heat exchanger. Once the number and magnitude of actual stress events has been determined, this information can be plotted on a stress intensity against number of cycles (S-N) curve for aluminum to predict the fatigue life for the heat exchanger.

A.4.1.5 The data needed to perform a remaining life assessment includes fluid compositions, fluid transport properties, heat curves, temperature, pressure and flow rate for all streams entering and leaving the plate-fin heat exchanger. Terminal data, i.e., at the inlet and outlet of the plate-fin heat exchanger, is usually adequate for the fatigue analysis as the heat exchanger thermal modeling software can perform the calculations to determine the metal temperature gradients throughout the heat exchanger. Inlet fluid conditions are input to the model and all other outlet data is useful to verify the model. However, in some cases, it may be desirable to install in-layer, side bar and/or end bar temperature measurement devices at specific locations on the heat exchanger to improve operational surveillance and operational stability, e.g., use metal temperature rather than stream outlet temperature for process flow control. Refer to the ALPEMA Standards for recommended good practice on instrumentation and monitoring of operation.

A.4.1.6 Careful planning, including consultation with the vendor, is recommended prior to purchase of the heat exchanger to ensure that adequate instrumentation is provided, along with the capability to collect, store, and retrieve the operating data needed for the analysis. Operating data should be recorded and stored at a no less than 1-minute intervals. Time stamps should always accompany the operating data to avoid the over-counting of temperature limit exceedances during transient events, which could occur with higher resolution data.

A.4.1.7 Excursion counters can be utilized to track occurrences related to fatigue stress in real-time, such as stream-to-stream temperature difference, temperature rate of change, or sudden flow rate or pressure changes . The excursion counter data can be shown on the operating screen or on regularly monitored dashboards to alert operators of events that have the potential to impact fatigue life. Regular monitoring of this data is important so that corrective action can be implemented to the operation or control system to reduce the number and magnitude of events that could reduce fatigue life or cause of leakage of the heat exchanger to occur.

A.4.1.8 For heat exchangers that have not been actively monitored over their operating history and operating data does exist, a screening of the past data is recommended to assess the number and magnitude of events that may impact the integrity of the heat exchanger and whether a more detailed review of the operating history is warranted. The events can be ranked by severity to determine if a more rigorous fatigue life analysis would be appropriate.

A.4.1.9 Rigorous heat exchanger rating software can be used to supplement terminal temperature data and provide internal temperature points when necessary to evaluate those against the operating guidelines.

A.4.2 Corrosion Allowance—Guidance to 7.6

A.4.2.1 Refer to the recommended good practice in ALPEMA Standards for information and precautions that should be applied to plate-fin heat exchangers in services containing water.

A.4.2.2 In all cases, the presence of halides and heavy metal ions should be avoided because elemental mercury is a trace contaminant in some natural gas feedstocks and may deposit over time as a solid foulant in cold service plate-fin heat exchangers. When equipment temperatures are raised above the melting point of mercury (e.g., during operational excursions or shutdowns), these deposits can liquefy and accumulate, resulting in degradation of aluminum through several mechanisms. For such cases, a mercury removal system should be considered.

A.4.3 Dissimilar Metal Flange Pairs—Guidance to 7.8.9

A.4.3.1 Bolted joints with dissimilar flange metallurgy are more susceptible to leakage than flanges with similar metallurgy. These connections are typically comprised of an aluminum flange that is integral with the plate-fin heat exchanger or cold box, a stainless steel piping flange, stainless steel studs or bolting, a gasket, and an insulation system with vapor barrier.

A.4.3.2 Some of the technical challenges when designing such joints include the following.

a) Differential coefficients of thermal expansion:

   — The difference in coefficients of thermal expansion between aluminum and stainless steel is a factor of approximately 1.5. Therefore, the aluminum flange will experience significantly more contraction while cooling than the stainless steel bolting and flange. When this occurs, there is potential for the bolt load to be reduced to the extent that is not possible to maintain adequate load on the gasket. Possible approaches to overcome thermal expansion problems may include the use of thermal compensating (i.e. negative coefficient thermal expansion) washers, or elastic spring washers.

b) Differences in component strength:

   — The strength of the aluminum components is less than that of the stainless steel components. Higher bolt loads are often used to accommodate differential thermal expansion. Aluminum flanges should be designed for the specific service to prevent excessive deflection under the applied bolt loads and external loads. Standard flange thicknesses are often not sufficient. Flat washers are sometimes used to limit indentation between the stainless steel nut and back side of aluminum flange.

c) Large piping loads:

   — Thermal piping loads can be large, and in some cases can be more significant than the pressure load. An aluminum to stainless flange joint may be less robust than those with matching materials. This effect should be considered during design and a pipe stress analysis should be required prior to completing the design of this connection.

d) Insulated joints:

   — Due to operating temperatures, these joints are normally insulated. This insulation impairs the ability to inspect the joint and undertake maintenance, including torque, during startup and operation. For this reason, additional consideration of the design of the joint is beneficial.

e) Gasket selection:

   — The use of gaskets with low seating stress will provide improved reliability. When selecting gaskets, the purchaser should realize that many gaskets that have low seating stresses also tend to have higher relaxation. Proper analysis of the gasket characteristics is required.

A.4.3.3 The purchaser and the vendor share the responsibility for the proper design of dissimilar metal bolted joints between the plate-fin heat exchanger and the piping system. This requires information exchange and coordination between the purchaser's piping engineer and the vendor. The following should be considered.

a) The supply of the mating flange, gasket, and bolting and the method of analysis to determine the adequacy of the flanged joint should be agreed between the purchaser and the vendor.

b) The purchaser should provide the details of the mating flange (connecting flange on purchaser's piping, including materials and dimensions), bolting and gasket to the vendor for the design of aluminum flange on the plate-fin heat exchanger unless the mating flange, including bolting and gasket, are supplied by the vendor.

c) If the mating flange, including bolting and gasket, is in the vendor's scope, the vendor should be responsible for the analysis demonstrating the adequacy of the joint. If the mating flange, bolting, and gasket are not provided by the vendor, the responsibility for the analysis should be agreed between the purchaser and the vendor.

d) The assembly bolt loads for the dissimilar metal joints must be chosen to ensure that enough gasket load is maintained during the specified operating conditions, including startup, shutdown, and upset conditions. This initial bolt load may be higher than the design load, and the flange analysis should consider this higher load, including the potential for excess flange rotation or permanent damage.

e) External piping loads indicated from the purchaser's detailed piping stress analysis should be considered in the design of the flanged joint. The acceptability of the external piping loads should be a matter of agreement between the purchaser and the vendor.

A.4.3.4 More discussion on this topic can be found in the following publications:

— ASME B31.3 Appendix L;

— ASME PCC-1 Appendix O; and

— WRC 538.

A.4.4 Unpressurized Inactive Areas—Guidance to 7.8.11

A.4.4.1 Brazed aluminum plate-fin heat exchangers often include unpressurized inactive areas equipped with vent and/or drain holes to prevent pressurization from leaks in adjacent active layers and allow means to detect such leaks. During shipping, handling, and storage, these vent and drain holes are sealed with shipping plugs to prevent the ingress of moisture, rainwater, insects, or debris. It is essential to remove these shipping plugs before the heat exchanger is put into operation, as per the manufacturer's recommendations.

A.4.4.2 Heat exchangers located inside a cold box, the vent and drain holes are typically left open to the cold box atmosphere. For standalone heat exchangers with insulation, vent lines should be installed on the vent and drain holes. These vent lines should extend outside the insulation. If vent lines are installed, valves should not be installed in the vent line or any device that would potentially over pressurize the inactive area. Vent lines should extend outside the insulation and be covered in a manner that prevents moisture, water, and insect ingress while allowing the release of process streams in the event of leaks from adjacent active layers. Purchaser should follow manufacturer's guidelines for the installation of vent lines and the covering of their openings.

A.4.5 Header Loading—Guidance to 7.8.12

The nozzle loads from attached piping are seldom defined at the time of order placement for a plate-fin heat exchanger. In addition, the allowable nozzle loads for these 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 vendor and piping designers work to establish 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 vendor to confirm their acceptability.

A.5 Materials—Guidance to 8

A.5.1 Materials for aluminum plate-fin heat exchangers are selected for their brazeability, weldability, and other characteristics. Typical materials used in construction, and their maximum applicable design temperatures, are shown in the ALPEMA Standards.

A.5.2 Vendors may provide recommendations regarding the suitability of fluids with aluminum materials; however, the responsibility for material selection and approval rests with the purchaser. For example, vendors do not assume responsibility or provide warranties concerning potential corrosion issues.

A.6 Fabrication, Backing Strips—Guidance to 9.1.6

A.6.1 Open root welding of aluminum materials is not a feasible or practical method for producing radiograph quality weld joints in plate-fin heat exchangers, pressure vessels, and pressure piping systems. There are many factors that affect the success of open root welding of aluminum, but the greatest difficulty is the inability to remove the thin aluminum oxide layer on the inside or backside surface of the base metal during the welding process. A thin aluminum oxide layer forms on all aluminum materials immediately after acid cleaning, grinding, sanding, or wire brushing prior to welding. During the arc welding process of aluminum, the flow of electricity from the base metal to the electrode across the welding arc removes and vaporizes this thin oxide layer for base metal surfaces that are directly contacted by the welding arc. But the welding arc does not contact the backside of the weld joint; therefore, the oxide layer is not removed. The oxide prohibits the backside of the material and weld from evenly melting and flowing together to form a consistent and solid weld. Using an inert backing gas during welding does not solve the problem since the oxide layer is present on the base metal before the backing gas can be applied. The visible appearance and radiographic examination of this type of weld usually indicates a greatly varied degree of weld penetration (both excessive and suck back) within the same weld, including areas of non-fusion and areas with linear and transverse indications that result from abrupt changes in the amount of internal penetration or reinforcement.

A.6.2 Given the problems with open root welding, aluminum backing strips/rings are utilized to perform full penetration welds on aluminum materials where the back side of the weld is not accessible for back grinding or back welding of the joint. The use of metal backing with aluminum materials gives support for the root of the weld and allows for a consistent amount of root penetration and quality, along with ease of radiographic interpretation.

A.6.3 The use of backing strips does not typically impact the ability to radiograph a weld; the joint configuration determines if radiography is possible. On rare occasions, a backing strip fit-up may make it difficult to read a radiograph; the backing strip should then be removed if possible.

A.7 Inspection and Testing

A.7.1Quality Control—Guidance to 10.1.2.a

A.7.1.1 The following weld joint types on a brazed aluminum plate-fin heat exchanger are those that can be radiographed and provide meaningful results: butt joints (i.e. nozzle-to-flange welds and tip portion welds of headers with mitered end welds), longitudinal seam welds, circumferential welds that are accessible for either film or digital radiography to the back side of the joint, and branch joint welds that are accessible for either film or digital radiography to the back side of the joint (i.e. nozzle-to-header welds).

A.7.1.2 A weld radiograph of a header-to-block weld joint is not useful because it is not possible to get the film in the header behind the weld and to have the radiation source perpendicular to the film. If the radiation source is at an angle other than perpendicular, the image will be distorted, and the size of any defect will appear larger than it really is. Thus, the radiograph can yield a false positive defect indication. It is noteworthy that, although the joint cannot be meaningfully radiographed, the design codes assign a joint efficiency to the joint that is appropriate for that joint type whether or not radiography is used.

A.7.1.3 Radiography of double fillet weld corner joints (i.e., header flat end welds) does not produce a useful image.

A.7.2 Sacrificial Mock-up Transition Joints—Guidance to 10.1.5.

A.7.2.1 The testing requirements described in 7.9.3 are intended for qualifying transition joint designs prior to their first use, through thermal cycling and subsequent helium leak testing.

A.7.2.2 The clause 10.1.5 provides an option that purchasers can choose to implement for additional quality control over the manufacturing process of production pieces using requirements of clause 7.9.3.

A.7.2.3 Applying Clause 10.1.4 requires manufacturing of mock-up piece(s) for testing. These mock-ups should be treated as sacrificial. Actual production pieces should not be used for this purpose, as installing service transition joints that have undergone thermal cycling tests is not recommended.

A.7.2.4 When the purchaser elects to apply this clause, only the minimum quantity and size of mock-up pieces necessary to validate the production process should be specified. The determination of minimum quantity should consider the number of production pieces that can be produced from each production lot, e.g. how many transition joints can be made from a single multi-layer explosion-welded plate.

A.7.2.5 Typically, this mock-up testing should only be considered when there are significant risks that need to be addressed, for example, risks identified through previous experience or when qualifying a new supplier.

Annex B
(Informative)

Plate-fin Heat Exchanger Checklist

B.1 Completion of the Checklist is the Responsibility of the Purchaser

This checklist is used for listing the purchaser’s specific requirements for which the paragraphs or subsections of API 668 include a choice or which designate, by use of a bullet (l) in the margin, that a decision is required.

Subsection	Requirement		Item	
4.1	Specify (or agree) pressure design code.	State required code		
4.2	Specify (or agree) structural welding code.	State required code		
4.3	Compliance with applicable local regulations.	State required regulations		
4.4	Is cyclic design service required? If yes, provide detailed information.	Yes (provide requirements)		No
4.5	Specify quantity of detrimental trace elements and need for mercury tolerant design per stream.	Specify quantities and mercury design requirement by stream.		
4.7	Is hydrogen service required? If yes, specify per stream.	Yes (specify per stream)		
4.8	Alternate operating conditions to be included.	Provide requirements.		
5.4	Specify if static head losses or gains to be provided with proposal.	Yes		No
6.1.3	Detailed information to allow the purchaser to undertake performance modeling.	Yes		No
6.2.2	Specify if copies of applicable welding procedure specifications, procedure qualification reports, and weld maps for review or record.	For review	For record	Not required
6.2.3	Specify if calculations to be furnished for review or record.	For review	For record	Not required
6.2.5	Specify pressure testing, leak testing, and drying procedures for review.	Yes		No
6.2.6	Specify inspection and test plan for review.		Yes	No
6.3	Format and quantities required for final documentation.	Provide requirements.		
7.2	Specify a maximum design temperature and a minimum design metal temperature per stream.	Complete on datasheet.		
7.3.1	Specify design pressure and vacuum requirements (if applicable) per stream.	Complete on datasheet.		

Subsection	**Requirement**		**Item**	
7.7.5	Specify requirements for and type of electrical grounding devices, if required.	Provide requirements.		
7.8.2	Specify requirement for self-draining and self-venting design.	Provide requirements.		
7.8.3	Is insulation required? If yes, specify insulation thickness.	Yes (provide thickness)	No	
7.10.1	Specify requirements for fluid or metal temperature indicating devices, if any.	Provide requirements		
7.10.2	Specify requirements for provide connections for differential pressure monitoring devices, if any.	Provide requirements		
10.1.1	Specify if information required on quality control system and if quality control plan required.	Yes (clarify requirements)		
10.1.5	Specify if a sacrificial mockup transition joint is required.	Yes (clarify requirements)		
10.2.11	Specify if external and Inter-stream helium leak testing required per ALPEMA acceptance criteria?			No
10.2.12	Specify if inter-stream helium leak testing to a tighter acceptance criteria than ALPEMA required?	Yes (specify requirements)		

Annex C

(Informative)

Plate-fin Heat Exchanger Datasheets

The following datasheets are provided to assist the designer, vendor, and user to specify the data necessary for the design of a plate-fin heat exchanger for petroleum and natural gas services. If a unit contains more than three streams (fluids), additional process datasheets should be used.

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

Company	**BRAZED ALUMINUM PLATE-FIN HEAT EXCHANGER DATASHEET (SI UNITS) PROCESS**	**Engineering contractor**
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Customer:	Item No.:
Project:	Manufacturer:
Location:	Order/enq. No.:

01 Service:			Total heat transfer area: (m^2)
02 Number of blocks:		Blocks connected in parallel:	Blocks connected in series:
03 No. blocks per assembly:	No. of assemblies:	Thermal transmittance (Overall heat transfer coefficient): $(W/m^2\cdot K)$	
04 Total number of layers (including dummy layers):		Flow pattern: counter, cross-counter, cross, parallel	
05		Block size: width (mm), height (mm), length (mm)	

06 Fluid		A/		B/		C/	
07 Total flow	(kg/s)						
08 Design temperature (maximum)	(°C)						
09 Minimum design metal temperature	(°C)						
10 Design pressure	[kPa (ga)]						
11 Pressure drop allow./calc.	(kPa)	/		/		/	
12 Static pressure loss	(kPa)						
13 Test pressure (hydrostatic/ pneumatic)	[kPa (ga)]	/		/		/	
14 MAWP	[kPa (ga)]						
15 **OPERATING DATA**							
16 Liquid flow (In/Out)	(kg/s)	/		/		/	
17 Vapor flow (In/Out)	(kg/s)	/		/		/	
18 Noncondensables flow	(kg/s)						
19 Operating pressure	[kPa (ga)]						
20 Operating temperature (In/Out)	(°C)	/		/		/	
21 Vacuum @ temperature	[kPa (abs) @°C]	@		@		@	
22 **LIQUID PROPERTIES**		INLET	OUTLET	INLET	OUTLET	INLET	OUTLET
23 Density	(kg/m^3)						
24 Specific heat capacity	(kJ/kg·K)						
25 Viscosity	(mPa·s)						
26 Thermal conductivity	(W/m·K)						
27 Surface tension	(N/m)						
28 **VAPOR PROPERTIES**							
29 Density	(kg/m^3)						
30 Specific heat capacity	(kJ/kg·K)						
31 Viscosity	(mPa·s)						
32 Thermal conductivity	(W/m·K)						
33 Relative molecular mass	(kg/kmol)						
34 Relative molecular mass, noncondensables	(kg/kmol)						
35 Dew point/bubble point	(°C)						
36 Latent heat	(kJ/kg)						
37 Critical pressure	[kPa (abs)]						
38 Critical temperature	(°C)						
39 Heat exchanged	(kW)						
40 Heat transfer area per block	(m^2)						
41 MTD (corrected)	(°C)						
42 Heat transfer coefficient multiplier							
43 Stream heat transfer coefficient	$(W/m^2\cdot K)$						

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Company	**BRAZED ALUMINUM PLATE-FIN HEAT EXCHANGER DATASHEET (SI UNITS) MECHANICAL**	**Engineering contractor**
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01 **BLOCK CONSTRUCTION DETAIL**				
02 Number of layers per block				
03 Effective layer width	(mm)			
04 Effective layer thermal length	(mm)			
05 Heat transfer fin type				
06 Fin height x thickness	(mm)	X	X	X
07 Fin perforation percentage	(%)			
08 Fin serration length or crest distance	(mm)			
09 Fin number per meter				
10 Distributor type				
11 Distributor fin type				
12 Fin height x thickness	(mm)	X	X	X
13 Fin perforation percentage	(%)			
14 Fin serration length or crest distance	(mm)			
15 Fin number per meter				
16 **CONNECTIONS**				
17 Nozzle size (inlet/outlet)	(DN)	/	/	/
18 Nozzle type/rating		/	/	/
19 Nozzle loads/moments	(N)/(N.m)	/	/	/
20 Inlet manifold size	(mm)			
21 Inlet manifold nozzle size (inlet/outlet)	(DN)	/	/	/
22 Inlet manifold nozzle type/rating		/	/	/
23 Outlet manifold size	(mm)			
24 Outlet manifold nozzle size (inlet/outlet)	(DN)	/	/	/
25 Outlet manifold nozzle type/rating		/	/	/
26 Header size (inlet/outlet)	(mm)	/	/	/

27 **COMPONENT**		
28 Parting sheet thickness:	(mm)	Parting sheet material:
29 Cap sheet thickness:	(mm)	Cap sheet material:
30 Side bar width:	(mm)	Side bar material:
31 Heat transfer fin material:		
32 Distributor fin material:		
33 Nozzle material:		
34 Manifold material:		
35 Header material:		
36 Nozzle pipes/flanges:		
37 Stud bolts/nuts:		
38 Support material:		
39 Piping connection type		
40 Pressure vessel code		
41 Material certificate type		
42 Applicable specifications		
43 Local rules and regulations		
44 Local registration of plate-fin heat exchanger		
45 Code stamp		yes/no
46 Stacking arrangement		
47		

48 Mass: Block (empty/operating)	(kg)	Assembly: (empty/operating)	(kg)

49 NOTES:
50
51
52

Company	**BRAZED ALUMINUM PLATE-FIN HEAT EXCHANGER DATASHEET (SI UNITS)**	**Engineering contractor**
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01 Stream Designation:	Fluid Name:												
02 Composition	Component												
	Mole %												

03					Liquid phase					Vapor phase							
04	Pressure [kPa (ga)]	Temperature (°C)	Heat released (KW)	Mass fraction vapor	Density (kg/m^3)	Specific heat capacity (kJ/kg·K)	Viscosity (mPa·s)	Thermal conductivity (W/m·K)	Surface tension (N/m)	Density (kg/m^3)	Specific heat capacity (kJ/kg·K)	Viscosity (mPa·s)	Thermal conductivity (W/m·K)	Relative molecular mass (kg/kmol)	Latent heat (kJ/kg)	Critical pressure [kPa (abs)]	Critical temperature (°C)
05																	
06																	
07																	
08																	
09																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
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26																	
27																	
28																	
29																	
30																	
31																	
32																	

Company	**BRAZED ALUMINUM PLATE-FIN HEAT EXCHANGER DATA SHEET (SI UNITS) CYCLIC SERVICE INFORMATION**	Engineering contractor
P.O. No.:	**Doc. No.:**	**Page 4 of**

1					
2					
3	**Description of Cyclic Service Operation**				
4					
5	Condition	Time	Duration	**Composition**	**Flow rate**
6		(h/min)	(h/min)		(kg/h)
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26	Condition	Time	Duration	**Temperature**	**Pressure**
27		(h/min)	(h/min)	(°F)	[kPa (ga)]
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45	**NOTES**				
46					
47					
48					
49					
50					
51					

Rev. No.	Description	Date	Prepared by	Reviewed by	

Company	**BRAZED ALUMINUM PLATE-FIN HEAT EXCHANGER DATASHEET (US CUSTOMARY UNITS) PROCESS**	**Engineering contractor**
PO No.:	**Doc. No.:**	**Page 1 of**

Customer:	Item No.:
Project:	Manufacturer:
Location:	Order/enq. No.:

01 Service:		Total heat transfer area: (ft^2)
02 Number of blocks:	Blocks connected in parallel:	Blocks connected in series:
03 No. blocks per assembly:	No. of assemblies:	Thermal transmittance (Overall heat transfer coefficient): (BTU/h·ft^2·°F)
04 Total number of layers (including dummy layers):		Flow pattern: counter, cross-counter, cross, parallel
05		Block size: width (in.) height (in.), length (in)

06 Fluid		A/	B/	C/
07 Total flow	(lb/h)			
08 Design temperature (maximum)	(°F)			
09 Minimum design metal temperature	(°F)			
10 Design pressure	(psig)			
11 Pressure drop allow./calc.	(psi)	/	/	/
12 Static pressure loss	(psi)			
13 Test pressure (hydrostatic/ pneumatic)	(psig)	/	/	/
14 MAWP	(psig)			
15 **OPERATING DATA**				
16 Liquid flow (in/out)	(lb/h)	/	/	/
17 Vapor flow (in/out)	(lb/h)	/	/	/
18 Noncondensables flow	(lb/h)			
19 Operating pressure	(psig)			
20 Operating temperature (in/out)	(°F)	/	/	/
21 Vacuum @ temperature	[(psia)@ °F]	@	@	@

22 **LIQUID PROPERTIES**		INLET	OUTLET	INLET	OUTLET	INLET	OUTLET
23 Density	(lb/ft^3)						
24 Specific heat capacity	(BTU/lb·°F)						
25 Viscosity	(cP)						
26 Thermal conductivity	(BTU/ft·h·°F)						
27 Surface tension	(dyne/cm)						
28 **VAPOR PROPERTIES**							
29 Density	(lb/ft^3)						
30 Specific heat capacity	(BTU/lb·°F)						
31 Viscosity	(cP)						
32 Thermal conductivity	(BTU/ft·h·°F)						
33 Relative molecular mass	(lb/lb·mol)						

34 Relative molecular mass, noncondensables	(lb/lb·mol)			
35 Dew point/bubble point	(°F)			
36 Latent heat	(BTU/lb)			
37 Critical pressure	(psia)			
38 Critical temperature	(°F)			
39 Heat exchanged	(BTU/h)			
40 Heat transfer area per block	(ft^2)			
41 MTD (corrected)	(°F)			
42 Heat transfer coefficient multiplier				
43 Stream heat transfer coefficient	(BTU/ft·h·°F)			

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Company	**BRAZED ALUMINUM PLATE-FIN HEAT EXCHANGER DATASHEET (US CUSTOMARY UNITS) MECHANICAL**	**Engineering contractor**
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01 **BLOCK CONSTRUCTION DETAIL**				
02 Number of layers per block				
03 Effective layer width	(in.)			
04 Effective layer thermal length	(in.)			
05 Heat transfer fin type				
06 Fin height x thickness	(in.)	X	X	X
07 Fin perforation percentage	(%)			
08 Fin serration length or crest distance	(in.)			
09 Fin number per inch				
10 Distributor type				
11 Distributor fin type				
12 Fin height x thickness	(in.)	X	X	X
13 Fin perforation percentage	(%)			
14 Fin serration length or crest distance	(in.)			
15 Fin number per inch				
16 **CONNECTIONS**				
17 Nozzle size (inlet/outlet)	(NPS)	/	/	/
18 Nozzle type/rating		/	/	/
19 Nozzle loads/moments	(lbf) / (lbf. ft)	/	/	/
20 Inlet manifold size	(in.)			
21 Inlet manifold nozzle size (inlet/outlet)	(NPS)	/	/	/
22 Inlet manifold nozzle type/rating		/	/	/
23 Outlet manifold size	(in.)			
24 Outlet manifold nozzle size (inlet/outlet)	(NPS)	/	/	/
25 Outlet manifold nozzle type/rating		/	/	/
26 Header size (inlet/outlet)	(in.)	/	/	/

27 **COMPONENT**		
28 Parting sheet thickness:	(in.)	Parting sheet material:
29 Cap sheet thickness:	(in.)	Cap sheet material:
30 Side bar width:	(in.)	Side bar material:
31 Heat transfer fin material:		
32 Distributor fin material:		
33 Nozzle material:		
34 Manifold material:		
35 Header material:		
36 Nozzle pipes/flanges:		
37 Stud bolts/nuts:		
38 Support material:		
39 Piping connection type		
40 Pressure vessel code		
41 Material certificate type		
42 Applicable specifications		
43 Local rules and regulations		
44 Local registration of plate-fin heat		
45 Code stamp		Yes/no
46 Stacking arrangement		
47		
48 Mass: Block (empty/operating)	(lb)	Assembly: (empty/operating) (lb)

49 NOTES:
50
51
52

Company	**BRAZED ALUMINUM PLATE-FIN HEAT EXCHANGER DATASHEET (US CUSTOMARY UNITS) PHYSICAL PROPERTIES**	**Engineering contractor**
PO No.:	**Doc. No.:**	**Page 3 of**
01 Stream Designation	Fluid Name:	

02 Composition	Component												
	Mole %												

03					Liquid phase					Vapor phase							
04	Pressure (psig)	Temperature (°F)	Heat released (BTU/h)	Mass fraction vapor	Density (lb/ft^3)	Specific heat capacity (BTU/lb·°F)	Viscosity (cP)	Thermal conductivity (BTU/ft h °F)	Surface tension (dyne/cm)	Density (lb/ft^3)	Specific heat capacity (BTU/lb·°F)	Viscosity (cP)	Thermal conductivity (BTU/ft h °F)	Relative molecular	Latent heat (BTU/lb)	Critical pressure (psig)	Critical temperature (°F)
05																	
06																	
07																	
08																	
09																	
10																	
11																	
12																	
13																	
14																	
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Company	**BRAZED ALUMINUM PLATE-FIN HEAT EXCHANGER DATA SHEET (US CUSTOMARY UNITS) CYCLIC SERVICE INFORMATION**	Engineering contractor
P.O. No.:	**Doc. No.:**	**Page 4 of**

1					
2					
3	**Description of Cyclic Service Operation**				
4					
5	Condition	Time	Duration	**Composition**	**Flow rate**
6		(h/min)	(h/min)		(lb/h)
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26	Condition	Time	Duration	**Temperature**	**Pressure**
27		(h/min)	(h/min)	(°F)	(psig)
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45	**NOTES**				
46					
47					
48					
49					
50					
51					

Rev. No.	Description	Date	Prepared by	Reviewed by

Annex D
(Informative)

Block-in-Shell Heat Exchangers

D.1 Scope

This informative annex describes the unique features of block-in-shell heat exchangers and provides general guidelines and recommendations for their mechanical design, process design, material selection, fabrication, inspection, testing, and shipping preparation and supply.

For the plate-fin heat exchanger of block-in-shell heat exchangers, see sections 1 through 11 of this standard.

D.2 General

Block-in-shell heat exchangers are alternatives to tubular heat exchangers that can be used as distillation column reboilers in cryogenic services or as refrigerant chillers to provide for process stream cooling or condensation.

Due to their compact nature, they can provide up to 10 times the surface area per unit volume as compared to tubular bundles for either reduced plot space or more duty for a given plot area. Their lightweight aluminum internal materials also can reduce the weight of the equipment.

Their high efficiency allows for closer temperature approaches than can be achieved with conventional heat exchangers, often down to 1 °C (2 °F). This can provide for increased plant capacity and/or operating horsepower savings for refrigeration systems.

Examples of their application include C2 and C3 splitter reboilers in ethylene plants, along with cascade refrigeration systems used for feed chilling in ethylene, LNG liquefaction, and natural gas processing services.

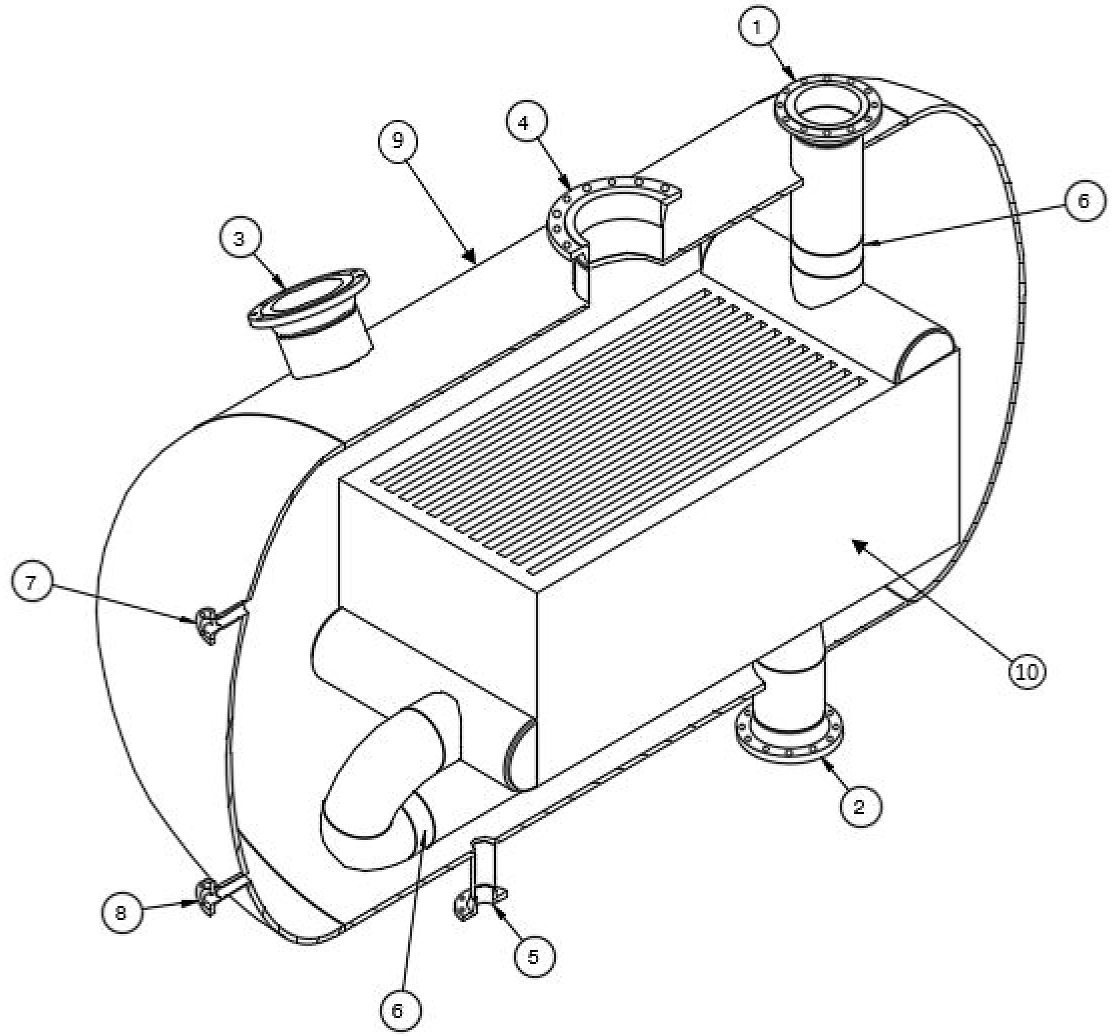
The block-in-shell heat exchanger consists of one or more plate-fin heat exchangers installed within a pressure vessel that is typically constructed of carbon steel, low-temperature carbon steel, or austenitic stainless-steel materials (see Figure D.1). The plate-fin heat exchanger is mounted horizontally within the pressure vessel. The warm process or utility stream enters the plate-fin heat exchanger through its inlet header and distribution section at the warm end of the block and then travels horizontally through the heat transfer finned passages in which it is confined. After being cooled, it exits the plate-fin heat exchanger through its outlet distributor and header. Nozzles are attached to the plate-fin heat exchanger inlet and outlet headers, and internal piping routes the process fluid through pressure vessel wall penetrations, where it terminates in flanged external piping connections. Bimetallic transition joints are provided on the internal piping when required by the materials of construction of the shell. The outlet piping is normally routed below the plate-fin heat exchanger back toward the warm end of the block where it exits the shell, as this allows for one end of the heat exchanger to “float” and minimizes thermal stress on the internal piping and block.

The cold stream, either a vaporizing column bottoms stream or a utility refrigerant, enters the shell through a conventional nozzle as either an all-liquid or two-phase mixture. Deflector plates or other special devices are sometimes used to distribute flashing two-phase streams. A cold liquid pool forms, whose height is maintained at or near the top of the plate-fin heat exchanger. The cold stream passages in the heat exchanger are left open at both the bottom and top of the block. The cold process fluid is drawn into the bottom of the heat exchanger, where it travels upwards and in a crossflow direction with respect to the warm process stream as it vaporizes and exits from the top of the block as a two-phase mixture. The cold flow is driven by natural circulation due to the static pressure difference between the two-phase mixture within the plate-fin heat exchanger passages and the liquid pool that surrounds the block.

As the two-phase mixture exits the top of the block, the liquid and vapor separate in the disengagement space provided in the pressure vessel above the plate-fin heat exchanger. The liquid falls back to the pool while the vapor exits the pressure vessel though conventional nozzles. Depending on the entrainment requirement for the exiting vapor, secondary separation devices, such as wire mist eliminator pads or chevron separators, may be provided.

The size of the pressure vessel is determined by the dimensions of the plate-fin heat exchanger it must contain while also providing a sufficient inventory and hold-up of the liquid pool and having adequate disengagement height and volume above the liquid pool and the heat exchanger to meet the exit vapor entrainment requirements. The pressure vessel is normally provided with instrumentation for level indication and control and may be provided with an internal weir to ensure liquid submergence of the block. A manway is normally supplied to provide access to the plate-fin heat exchanger and any internals for inspection and maintenance.

Refer to the ALPEMA Standards for additional information on block-in-shell heat exchangers.



Key

1	warm fluid inlet
2	warm fluid outlet
3	boiling fluid vapor outlet
4	boiling fluid inlet
5	boiling fluid drain
6	bimetallic transition joints
7	level instrument connection (upper)
8	level instrument connection (lower)
9	pressure vessel
10	plate-fin heat exchanger

Figure D.1—Block-in-Shell Heat Exchanger

D.3 Design

The design of the shells, including nozzles and internal piping, should conform to applicable codes and standards specified by the purchaser.

The shell and the block should be designed for the conditions specified by the purchaser. Blocks(s) and shells should be designed to withstand the dead loads, lateral loads, thermal loads, and all other applicable loads specified by the purchaser. External pressure acting on the block and any internal piping should be considered.

The design pressure indicated on the purchaser's datasheet should be considered maximum allowable working pressure (MAWP) for the block-in-shell heat exchanger.

All shell nozzles should use set-in type connections with full penetration welds. Shell/header reinforcement calculations at nozzles should consider the block and shell design pressures acting independently for nozzle wall and shell/header thickness calculations.

Nozzles connecting to the internal piping and block penetrate the shell wall and may be worthy of special considerations pertaining to the weld joint detail to be used, design analysis (including nozzle reinforcement and load requirements), and any nondestructive examination to be applied. In addition, when the block side materials and nozzles have a different operating temperature, material, and/or minimum design metal temperature than the shell components, further analysis may be required.

The internal piping that connects to the block should be designed with sufficient flexibility to avoid over-stress at the connections to the block and at the shell wall and should be stress analyzed. Internal gasketed joints should not be used.

If liquid is present, drainage in the installed position should be provided for all blocks, manifolds, and headers into connecting piping and for any dummy passages open to the shell side.

When multiple blocks are provided within a shell, these should be mounted so that the top of the blocks are at, or near, the same elevation. Blocks should have equal depths in the refrigerant liquid pool to allow them to continue operation at reduced liquid levels.

The internal supports for block(s) and external supports for the shell must accommodate thermal expansion and contraction during operation. Bolt holes should be slotted and sized to accommodate at least 1.5 times the calculated movement for maximum and minimum design temperature.

When multiple nozzles are provided on the shell, the distance between nozzle welds, welds between reinforcing pads, or to the circumferential and longitudinal seams, should be at least 50 mm (2 in.) to limit stress concentrations.

Demisting pads or other separation devices and supporting members should be mounted in a method that provides rigidity and positive retention, especially during upset conditions that can include very high liquid levels. Fasteners should be robust and adequate in number to resist failure or loosening in upset conditions. Internals should be designed to be removable through a manway.

The number of inlet and outlet nozzles, along with their location along the length of the shell, should be chosen such that the design liquid entrainment can be achieved with the consideration of nonuniform vapor generation rates along the length of the block(s) and the presence of inlet flash vapor loads.

For shell side streams that are two-phase at their inlet, the design of the inlet should be such that it avoids liquid falling directly on top of the block(s) and splashing droplets from being entrained into vapor outlet nozzles. Deflection plates or other distribution devices may need to be considered.

Vortex breaker(s) should be provided at any refrigerant liquid outlet connection, or drain line, in the bottom of a shell to avoid vapor entrainment, if required by the downstream equipment. Alternatively, self-venting nozzles may be used.

D.4 Materials of Construction

The purchaser should specify the materials of construction for the shell and internal piping, supports, appurtenances, etc., along with the corrosion allowance to be applied.

The transition joint material, internal piping material connected to the transition joint, and piping material protruding through the shell should be compatible with both the shell side and the “block side” fluid and should take into consideration the shell side corrosion allowance and the materials used. Transition joints should be of the type that do not use reinforcing flanges.

All load-bearing attachments to the shell should be made of same material as the base metal to avoid material toughness and brittle fracture concerns at low temperatures.

The saddle-bearing plates of the shell supports should have the same nominal composition as the shell and should be continuously welded directly to the shell.

If alloy linings are specified by the purchaser, they should be weld-overlay, integrally clad, or explosion-bonded. Loose liners or sleeves should not be used.

If cladding (including weld overlay) is used, the full cladding thickness including weld-overlay restoration should be used only as corrosion allowance and not considered for the pressure envelope.

Weld overlays (including weld-overlay restoration) should 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.

D.5 Fabrication

Post-weld heat treatment (PWHT) of the internal piping in close proximity of the transition joints and aluminum piping should be avoided in order to avoid the adverse impact on transition joints by exposure to high temperature. PWHT of these joints should be eliminated, where possible, either through the exclusions allowed in ASME B31.3, Paragraph 331.2.2 or by using stainless steel piping components inside of the pressure vessel. When PWHT is required, special care should be taken to protect transition joints and aluminum piping (for example, by use of adequate insulation).

Cleanliness is very important during fabrication around plate-fin heat exchangers. Care should be taken during assembly to protect blocks, especially the top of the blocks, where thin components, e.g., fins and parting sheets, are exposed.

D.6 Inspection and Testing

If hydrotesting is to be performed, potable water should be used. Chloride content of hydrotest water used for stainless pressure vessels should be limited to 50 mg/kg (50 ppm by mass).

Field hydrotesting of block-in-shell heat exchangers is strongly discouraged, as failure to remove all water after completion of hydrotesting could cause the heat exchanger to freeze and burst when placed in service. If performed, the heat exchanger should be soaked in methanol following the hydrotest to displace all free water prior to placing the heat exchanger back in service.

D.7 Preparation for Shipment

The block should be braced for shipment to prevent movement and damage during shipment.

Temporary shipping braces should be installed and clearly marked. These braces are to be removed prior to putting the equipment in service. A warning tag should be affixed to the shell indicating the need to remove the bracing prior to operation.

Both sides of the block, including the internal volume of the shell, should be dried prior to shipment.

Immediately after drying, the nozzles should be hermetically sealed and both pressure chambers should be pressurized with dry, oil-free nitrogen gas to a minimum gauge pressure of 20 kPa gauge (3 psig). One connection on each circuit should be provided with a pressure gauge and valve to allow for refilling as necessary.

All connections should be suitably labeled to indicate that the block-in-shell is shipped under nitrogen pressure.

Annex E

(Informative)

Cold Box

E.1 Scope

This informative annex describes the unique features of a cold box and provides general guidelines and recommendations for their design, materials selection, layout, fabrication, inspection, testing, and preparation for shipment. Refer to the ALPEMA Standards and vendor's installation, operation, and maintenance (IOM) manual for additional guidance on cold box.

E.2 General

A cold box is an enclosure used to house cryogenic equipment including plate-fin heat exchangers, distillation columns, separation drums, interconnecting piping, valves, and associated instrumentation. It provides structural support for the equipment and piping, as well as containing insulation suitable for cryogenic operation and protects these components from the atmosphere.

The main cold box structure is self-supporting and typically made from structural shapes (e.g., structural tubing). It is enclosed on its sides by panels which are continuously welded to the structure, as well as floor and roof panels to complete the structure. The cold box roof is considered as a maintenance platform and is typically of checker plate material. The cold box may be of rectangular or circular footprint. The cold box is typically provided with legs and baseplates, designed to be set on a foundation. The height of the legs should be sufficient to provide adequate air space below the floor to prevent cold temperatures at the based plate and foundation heaving. . The cold box enclosure is typically considered to be a confined space; proper personnel access procedures should be followed prior to entry.

Internal equipment and piping within the enclosure are supported on crossbeams. The internal support beams are usually of stainless-steel materials, although carbon steel or impact tested carbon steel materials may be used for warmer operating temperatures. A heat breaking insulating material suitable for cryogenic operating temperatures is typically installed between the equipment and piping supports and the structural support members to both facilitate the thermal contraction movement of the equipment relative to the support and provide an insulation barrier between the two members.

Piping is provided within the cold box for the interconnection of internal process equipment. Additionally, terminal process and utility stream connections penetrate the cold box casing for connection to the plant piping systems. The internal piping is typically aluminum or stainless-steel materials, although carbon or impact tested carbon steel may be used for warmer temperatures. Bi-metallic transition joints may be provided as required for the interconnection of equipment of different metallurgy, or when required for the connection to the external piping systems. Piping flexibility should be provided due to the compact nature of the cold box design and layout, and the cryogenic operating temperatures. For this reason, the piping penetrations through the cold box side panels is normally accomplished through flexible insulated close-out 'boots' that are designed to allow for the piping movement while providing an air-tight seal. Because the piping connections are not anchored to the cold box wall, this adds complexity to the design and analysis of the piping system(s) which must then consider both internal and external piping segments between analysis nodes. For smaller connections with adequate piping flexibility, fixed nozzle penetrations may be used.

Piping within the cold box should utilize welded connections only. Bolted or threaded connections should not be used inside of the cold box due to the lower reliability of these joints and their inaccessibility for inspection or maintenance.

When valves are included in the cold box scope as part of the piping system, these are typically provided with an extended bonnet with the actuator and positioner located outside of the cold box. The valve body, as well as other piping components which may require maintenance access, can be located in a 'Valve House'; an internal compartment of the cold box, segregated from the main cold box environment which is provided with a removable cover and packed with traditional cryogenic insulation materials. Flanged connections may be used within the 'Valve House'.

The cold box casing is normally provided with duplicate pressure design code nameplates for each of the equipment items installed within the cold box. These duplicate nameplates are normally located near grade. In addition, each piping connection into and out of the cold box is typically provided with a stream identification tag located at each nozzle.

The open space within the cold box is normally filled with an expanded Perlite insulation. Raw perlite is a volcanic stone containing water which when heated to temperatures above 1800°F (1000°C) expands into a lightweight granular material. It can be expanded on site and blown into the cold box or delivered already expanded in sacks for manual loading. Cold boxes must be provided with an adequate number and size of perlite loading connections, as well as suitable draining/dump connections. Manways may also serve the purpose of a perlite filling connection. The cold box is normally vibrated gently during the insulation filling operation to ensure that perlite gets distributed evenly throughout the box. Due to settling, it is expected that the insulation may have to be topped off after a few weeks of operation. Draining the entire insulation volume of the cold box from a grade located manway may present a hazard risk to personnel in the area. Removing perlite is normally performed by vacuum truck extraction from the top or mid-level access connections depending on the size of the cold box. Refer to the IOM manual and EIGA document 146 for information regarding perlite management.

Equipment and piping within the cold box operating at different temperatures should have sufficient clearances to achieve required insulation thickness so as not to reduce the thermal efficiency of the cold box. Adequate insulation space should also be provided between equipment and piping as well as between these internals and cold box casing/structure to prevent cold spots and sweating on exterior. .

To isolate the cold box atmosphere from the external environment, protecting the insulation from damage and maintaining an oxygen free environment, the cold box is operated under a dry nitrogen environment at slightly positive pressure; approximately 7.5 mbarg (3 inches of water column). The nitrogen is fed into the cold box through an internal perforated nitrogen purge tube/ring located at the bottom of the cold box. Depending on the height of the box, additional distribution rings may be required. The distribution tube/ring is normally fiber wrapped at the perforations to prevent localized jetting into the perlite bed. A continuous purge flow of nitrogen is taken from the top of the cold box through a breather valve. This valve may also serve as a vacuum breaker. The continuous purge flow is typically sized to achieve one cold box volume change in 24 hours. A higher purge rate, typically 2 to 3 volumes in 24 hours, is sometimes used for the initial dehumidification of the cold box atmosphere.

The continuous nitrogen purge flow is normally sampled for the presence of hydrocarbons, which would indicate a leak from the equipment or piping contained within the cold box. The nitrogen purge system typically mounted external to the cold box and may include pressure gauges, pressure regulators, flow control valves and flow meters

The cold box enclosure must be provided with one or more over pressure relief devices to prevent the over-pressurization of the enclosure resulting from the loss of pressure containment from internal piping or equipment. When these devices are located on the cold box roof, they may also serve as manways or perlite fill connections if appropriately sized.

The cold box enclosure may be provided with pressure indication devices or sample connections at various locations and elevations based on the size of the cold box and layout of the equipment. These may be routed to a common location near the base of the cold box for ease of access.

Internal instrumentation including temperature indicating devices for process fluid or metal temperatures, process pressure gauges and pressure differential devices, level indicating devices, etc. are normally routed to the exterior of the cold box, near the base when possible. The routing of wiring and impulse lines must be suitable for the operating temperatures and temperature gradients from their location to the cold box wall and down to grade. Temperature devices, RTDs or thermocouples, are typically provided as dual instruments and terminated in a junction box near the base.

Access manways are typically provided at the cold box base and on the roof. The over pressure devices may serve as a manway if appropriately sized. Additional manways may be provided at intermediate elevations when necessary to provide maintenance access to equipment, piping, or instruments at those locations.

Typically, the roof of the cold box is considered as a maintenance platform and should be equipped with guardrails, handrails, and safety gates. A davit may be provided to facilitate the lifting of maintenance equipment and insulation sacks.

Intermediate service platforms may be provided for access to locations where routine maintenance or inspection activity is expected.

The cold box may be provided with external stairs or ladder access from grade to any intermediate service platforms as well as to the cold box roof if access to these locations is not provided by free-standing structures. The cold box is not normally provided with internal ladders or maintenance platforms; erected scaffolding is typically used when maintenance or inspection is required.

The cold box structure is provided with lifting devices suitable to handle erection from its shipping to its fully erected position. Temporary internal shipping braces are sometimes provided for equipment and piping supports and are to be removed prior to operation. Temporary internal bracing, where provided, should be designed to be a bolted style to allow for removal without cutting or grinding, and should be uniquely numbered and identified for removal (e.g., through color coding).

The main advantage of a cold box is that it comes as a modular assembly and ready for installation on its foundation or structure. The compact nature of the equipment and piping layout, results in a significant reduction in the required plot area as compared to stick-built construction.

The disadvantage of a cold box is that the contained equipment, piping, and instrumentation is not readily available for inspection or maintenance. An additional pressure protection and purge system is required for the enclosure, with monitoring for the identification of equipment and piping leaks.

E.3 Design

E.3.1 Cold Box Casing and Structure

Casing and structure should be designed including following: Internal pressure resulting from nitrogen purge and relief device settings, loads resulting from internal equipment/piping including fluid weights, insulation loads, along with specified ambient conditions including wind, seismic and snow loadings.

The roof of the cold box should be designed for required dead load, live loads, and maintenance requirements.

Cold box structure and casing should be designed to accommodate loads imposed by any external appurtenances such as platforms and ladders as agreed between the vendor and purchaser.

Transportation loads should be considered during the design based on the intended mode of transport. Effect of the transportation loads should also be considered on the piping and equipment within the cold box. The mode of transport and applicable loads are to be agreed between vendor and purchaser.

E.3.2 Cold Box internals

Due to the design of cold boxes, pressure containing joints are typically inaccessible during normal operation. They should be welded joints in lieu of flanged to minimize potential leakage. Where flanged joints may be required, such as control valve or flow measuring devices, they should be located outside the cold box or within an externally accessible compartment which should be provided with its own insulation.

The externally accessible compartments are typically outside of the perlite filled section allowing for easier access, maintenance, and repair, and should have continuous nitrogen purge. The nitrogen purge to these compartments could be a separate purge system or be included as a part of the main enclosure purge system. Pipe penetrations to and from these access compartments to the interior of the cold box should permit movement of the piping.

Any special equipment and piping layout requirements (e.g., straight run, venting, draining, no pockets, minimum elevation) should be specified by the purchaser.

It is a good practice, where possible, to locate transition joints in low stress areas of the piping system.

The allowable nozzle load procedure for heat exchangers located in cold boxes and assemblies is the same as listed in ALPEMA Standards. The scope of work is as follows:

- For pipe-runs that attach to equipment inside the cold box (e.g. heat exchangers, vessels, drums, columns) and exit the cold box, the supplier should provide the allowable pipe loads and thermal movement at the header to nozzle intersection. The scope for pipe stress analysis for the interface piping and the responsibility of the analysis should be agreed between the purchaser and manufacturer.

- For pipe-runs that start and end within the cold box, the supplier is responsible for the pipe stress analysis.

  Note: The flange interface (connector of the cold box to the plant piping) should not be considered an anchor: that would not be a technically sound assumption since the flange is not the true anchor of the piping system.

Internal layout of cold box should allow free flow of perlite insulation to all void areas within the cold box which should be aided by strategically locating the perlite fill nozzles.

The design of the cold box should be such that it provides enough clearance below the roof so the top most process piping have required perlite insulation post perlite settlement.

E.4 Material of Construction

The external structural framing members are typically carbon steel, e.g., ASTM A500. The casing (roof, floor and side walls) are typically carbon steel, e.g. ASME SA-36.

The internal structural steel members for equipment supports, pipe supports, etc. are typically made of stainless-steel material, e.g., SS 304/304L. Structural steel members should be joined by welded connections. Structural steel pipe members are typically ASME SA-312 and welded built-up members are typically ASME SA-240.

Cold box roof is typically checker plate or provided with a non-skid coating for personnel safety.

When bolting is used to join equipment to their support members inside the cold box, stainless steel bolting is typically used.

The side, top and bottom plates of access compartments that house flanged components (i.e. control valves, flow elements) requiring routine maintenance, consideration should be given to use stainless-steel material or low temperature carbon steel to address potential for cracking in the event of a flange or valve leak. Alternatively, carbon steel may be used if suitable for the operating temperatures.

Flexible cold box wall penetrations are typically made of rubber material suitable for the environment.

E.5 Fabrication

Fabrication of equipment, piping and structural steel should be in accordance with the applicable codes and standards.

The casing (roof, floor, and side walls) should be continuously welded (typically from one side). Piping penetrations through the roof should be avoided. If a piping must penetrate through the roof and it is seal welded to the roof, a stress analysis should be performed.

For welding requirements of stainless steel and aluminum pressure components including requirements for the use of backing strips, refer to 9.1.

Vendor should take necessary precautions to prevent arc strikes, weld splatters or physical damage to transition joints during the fabrication process.

Flanges should not be used inside the cold box unless where necessary (i.e., manways for equipment, control valves, flow elements). When used, flanges should be accessible through access boxes without removing insulation from the main cold box volume.

Temporary supports should be painted in contrasting color and clearly tagged to specify they are removable. The temporary supports should be bolted type which can be easily removed through cold box manways.

Equipment and components should be inspected when received at cold box assembly yard prior to cold box fabrication activities. During all stages of fabrication, the vendor should clean the inside and outside of piping spools and equipment of all loose scale, dirt, sand, weld spatter, moisture, debris, chips, etc. by appropriate means. Vendor should maintain a clean workplace in and around the equipment. Pipe assemblies should be blown out with dry compressed air and the inside of each assembly inspected for cleanliness before it is closed for storage or transport, and prior to performing closure welds. Open ends of clean assemblies should be suitably closed to prevent the entrance of foreign matter or rain water during the fabrication activities.

E.6 Inspection and Testing

E.6.1 General

This section provides guidance on the Inspection & Testing of the Cold Box assembly during the fabrication process at supplier’s facility.

For inspection and testing requirements after the installation and during the operation, refer to the ALPEMA Standards, vendor drawings and vendor’s installation, operation, and maintenance (IOM) manual.

Supplier should provide an Inspection and Test Plan (ITP) for the cold box. The ITP should include inspection and testing activities for the piping system within the cold box, and overall cold box assembly at different stages of the fabrication. Other components within the cold box (heat exchangers, vessels, valves and instrumentation etc.) are not considered in this section which should have their separate ITPs.

E.6.2 Inspection of Cold Box at Fabricator

During the cold box fabrication process, the sequence of the inspection activities should follow the fabrication process, and so ensure that the finished cold box is in accordance with the applicable pressure/structural design codes and fabrication drawings.

The Inspection at supplier’s facility should also include the following:

- Verification of the coating system on exterior and interior of carbon steel surfaces in accordance with Purchaser’s specification.

- Trial fit of shipped loose components such as ladders and platforms, as applicable prior to the shipment.

E.6.3 Inspection Techniques at Fabricator

The following inspection techniques should be considered:

E.6.3.1 Visual Inspection of the Cold Box

Prior to the shipment, visual inspection of the cold box exterior and interior should be carried out to ensure the compliance with supplier drawings and P&IDs. For complex cold boxes, multiple visual inspections may be required at different stages of the fabrication to ensure the compliance with supplier’s drawings and P&IDs as the completed cold box may not have a full access to the interior for the inspection.

When transition joints are installed in a cold box piping system, a visual inspection should be conducted to verify the compliance with clause 7.9.5.

E.6.3.2 Dimensional Inspection

During the fabrication of the cold box and assembly of equipment and piping within it, regular dimensional inspections should be carried out to ensure that all items are in accordance with the approved fabrication drawings.

E.6.3.3 NDE Inspection of Welded Joints

During the assembly of the piping system within the cold box, pressure retaining welds should be examined in accordance with the pressure design codes (equipment & piping).

The following should be considered:

- Visual inspection of all pipework root welds;
- Liquid Penetrant inspection of all connecting pipework and cap welds;
- Radiographic Examination

Due to inaccessibility of the cold box interior during operation, routine inspection is typically not performed on the internals and purchaser may specify additional testing to ensure the quality of the welds (PMI, ferrite testing of stainless-steel piping etc).

E.6.3.4 Pressure Testing of Piping System after Assembly

After completion of all fabrication activities, , each pressure circuit within the cold box should be subject to a pneumatic pressure test in accordance with applicable piping code considering applicable safety regulations. Dry air or oxygen-free nitrogen with a dewpoint not higher than -40°C (-40 °F) should be used to perform the pressure test.

E.6.3.5 Leak Testing of Cold Box Enclosure

After completion of the cold box, a leak test of the enclosure should be performed using dry air. This typically includes a pressure decay criterion along with soap bubble testing at casing attachment welds and nozzle penetrations.

E.6.4 Inspection of the Cold Box at Site

Upon receipt of the cold box at the site, cold box inspection/testing should be performed in accordance with supplier’s IOM, erection drawings and applicable sections of the ALPEMA Standards.

Special attention should be paid to the removal temporary bracing or restraints used for shipping and handling.

Flexible nozzle penetrations should be visually inspected for any damage.

E.7 Preparation for Shipment

The external surface of the cold box is normally provided with a finished coating system that is suitable for the installation in accordance with purchaser’s specification. The cold box roof is sometimes provided with a non-slip coating. The inside surface is typically not coated as it operates in an inert atmosphere, although it may be provided with a primer coat when required for transportation or storage.

When the cold box is to be stored for an extended period of time the manufacturer should be consulted and may recommend operating the nitrogen purge system to protect the inside surface of the cold box and enclosed equipment and piping. Desiccant or other vapor phase corrosion inhibitors can also be provided within the cold box prior to shipment.

The piping and equipment systems within the cold box are normally sealed at both inlet and outlet connections with blinds or shipping covers and shipped under a dry nitrogen atmosphere between 5 and 15 psig (0.3 to 1.0 barg). Provisions are provided on each system to monitor and re-charge with nitrogen as necessary. The cold box enclosure itself is not shipped under any inert atmosphere.

Externally located components such as instrument transmitters, breather/vacuum valves, pressure relief devices, external components of the nitrogen purge system, and appurtenances (e.g., ladders, platforms, railings) are normally shipped loose.

Bibliography

[1] EN 13445[3], (all parts), *Unfired pressure vessels*

[2] WRC 538[4], *Determination of Pressure Boundary Joint Assembly Bolt Loads*

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

[4] GPA-TB-001, GPA Midstream Technical Bulletin – Brazed Aluminum Heat Exchangers

[5] **EIGA 146**[5], Perlite Management

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[3] European Committee for Standardization (CEN-CENELEC), Avenue Marnix, 17, B-1000, Brussels, Belgium, www.cen.eu.

[4] Welding Research Council, P.O. Box 201547,Shaker Heights, Ohio 44122

[5] European Industrial Gases Association, Avenue de l’Astronomie 30 B 1210 Brussels