INSTALLATION, OPERATION, AND MAINTENANCE MANUAL

for Chart Brazed Aluminum Heat Exchangers (BAHX) and Core-in-Kettle® Assemblies.

Cooler By Design.®

JANUARY 2022

ARRIVAL, INSTALLATION, AND STARTUP CHECKLISTS

The following checklists are for reference only, and are not intended to be comprehensive for all situations.

Serial Number:	
Plant Item Number:	

BAHX Arrival	**Relevant IOM Section**	**Checked By / Date**
1. Verify nameplate and record serial number	II. A.	
2. Check for external damage	II. A.	
3. Verify shipping stream pressure (typically 15 psig, if applicable)	II. A.	
4. Store per IOM instructions	II. B.	

BAHX Installation		
1. Verify nameplate serial number		
2. Lift into position following general lifting instructions in IOM and specific instructions supplied with unit (if applicable)	II. C.	
3. Verify correct BAHX orientation and nozzle locations	II. D. 1.	
4. Install Micarta® or equivalent insulation between support angle mounts and mating support surfaces (if applicable)	II. D. 1. c.	
5. Tighten bolted support connections to finger tight only (does not apply to bolted flange pipe connections)	II. D. 1. e.	
6. Verify no water or debris trapped in field piping to be attached to BAHX.	III. B. 1.	
7. Connect all nozzles to pipes	II. E.	
8. Connect Smart Layer® (if applicable)	II.1.4.	
9. Remove all temporary shipping supports	II. D. 1. a.	
10. Remove all vent plugs (if applicable)	II. F.	
11. Perform piping system leak / proof test	III. A., IV. A.	
12. Install insulation	II. G.	

BAHX Initial Startup		
1. Verify overpressure protection for all streams	III. C. 2.	
2. Verify filters installed for all applicable streams	III. B. 1.	
3. Verify no water trapped in or upstream of BAHX	III. C. 1.	
4. Bring to operation conditions following IOM instructions, **with special attention to temperature rate of change guidelines**	III. C. 3.	

FIGURE I

Basic Components of a Chart

Brazed Aluminum Heat Exchanger (BAHX)

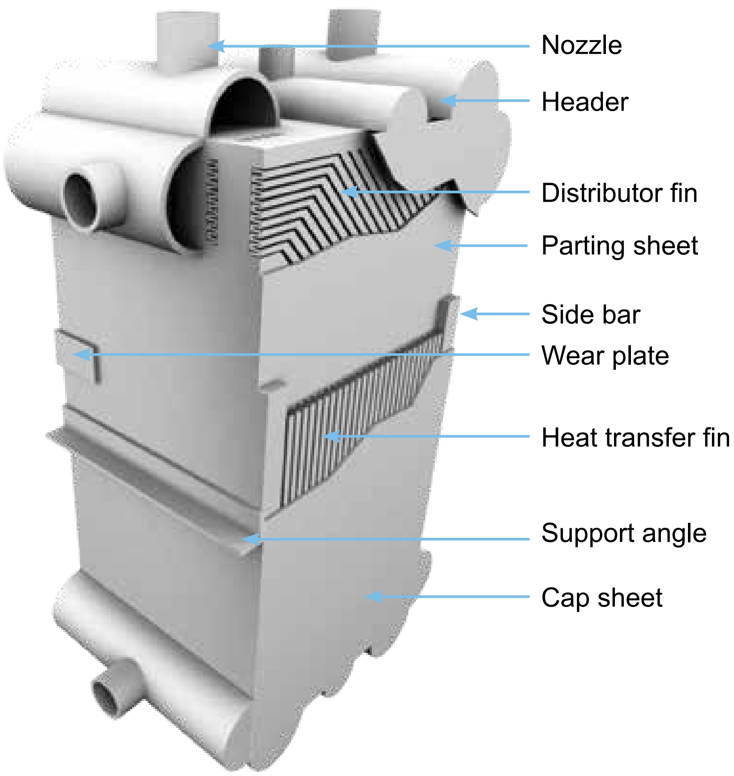
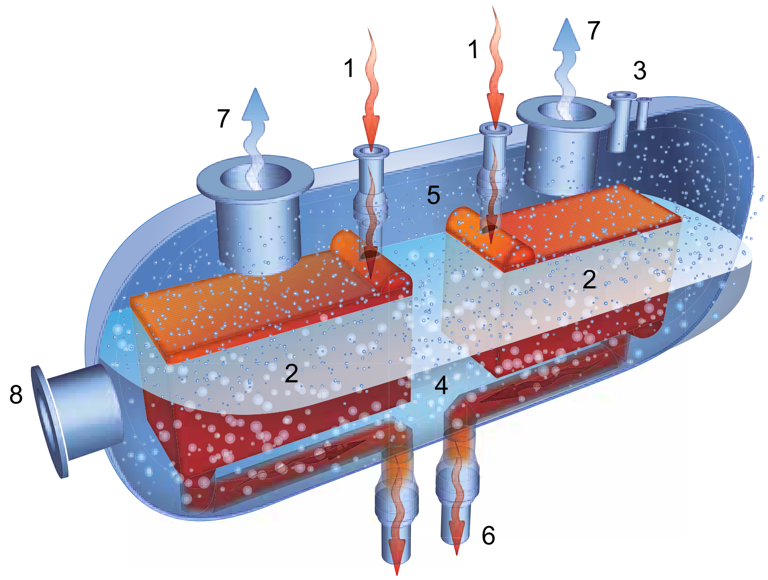


FIGURE II

How a Chart Core-in-Kettle® Works

1. The warm process stream fluid enters the Brazed Aluminum Heat Exchanger (BAHX) through steel inlet nozzle(s) on the vessel shell. The inlet nozzles are connected to the aluminum inlet pipes of the exchanger by an aluminum to stainless steel transition coupling.
2. Inside the BAHX the warm stream cools as it flows against a cold stream.
3. The cold stream enters the vessel either as a liquid or 2-phase fluid directly from a distillation column (or expansion valve in the case of a refrigerant).
4. A liquid level is formed outside the BAHX core to create a liquid head that drives the cold stream liquid through the core
5. A disengagement space above the core causes the liquid and vapour to separate.
6. The cooled warm stream leaves the BAHX and vessel.
7. The cold stream vapour exits the vessel through the outlet nozzles whilst the liquid falls back to be recirculated.
8. A manway is provided in the vessel shell.



The Chart Energy & Chemicals, Inc. ("Chart") brazed aluminum heat exchanger (BAHX) business began in 1985 with the acquisition of The Trane Company's BAHX operation in La Crosse, Wisconsin. Chart is a recognized global leader in the design and manufacture of large BAHX, battery assemblies, and cold boxes for cryogenic applications.

Chart incorporates the former Altec and Marston BAHX brands and consequently all rights to engineering and equipment produced by these companies.
"Core-in-Kettle" is a registered trademark of Chart Energy & Chemicals, Inc.

Brazed aluminum heat exchangers are also referred to as plate fin heat exchangers and abbreviated to PFHE within the industry.

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FOREWORD

This manual includes Chart's instructions, practices, and procedures regarding installation, operation, and maintenance of Chart BAHX, assemblies, and Core-in-Kettle® assemblies. Please contact Chart Lifecycle for assistance in the installation, commissioning, and startup services related to this equipment. Chart highly recommends these OEM trained services to assure a successful equipment startup.

This manual is based on extensive experience, including more than 60 years in the design and manufacture of BAHX for low temperature applications, including air separation and liquefaction, natural gas processing and liquefaction, helium liquefaction, and hydrogen, ethylene, and other light hydrocarbon product recoveries.

THROUGHOUT THIS MANUAL, SAFETY ITEMS ARE HIGHLIGHTED IN CAPITAL LETTERS AND LABELED WITH THE CAUTION MARK SHOWN HERE.

This manual is updated periodically. Before attempting any procedure you should verify with Chart that you are using the current version.

This manual cannot cover all possible variations in equipment design or provide answers to all specific installation, operation, and maintenance questions that may arise. If for any reason, any variations or questions arise that are not addressed in this manual, or any of these instructions, practices, and procedures cannot be followed, the contractor or owner must contact Chart for further information, interpretation, and guidance. Failure to follow the instructions, practices, and procedures may result in serious bodily injury or death, property damage, irreparable damage to the Chart equipment, and the voiding of any warranties applicable to the equipment.

When these instructions, practices, and procedures are followed, extended and reliable service from BAHX and Core-in-Kettle® assemblies can be expected.

THESE ITEMS SHOULD BE READ WITH EXTREME CARE AND THOROUGHLY UNDERSTOOD BEFORE COMMENCING ANY INSTALLATION, OPERATION, OR MAINTENANCE OF CHART EQUIPMENT. FAILURE TO PROPERLY FOLLOW INSTRUCTIONS SO DESIGNATED COULD RESULT IN RUPTURES OR EXPLOSIONS OR OTHER DANGEROUS SITUATIONS WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

DO NOT MODIFY THE EQUIPMENT OR DEVIATE FROM THE INSTRUCTIONS, PRACTICES, AND PROCEDURES IN THIS MANUAL.

THE CONTRACTOR OR OWNER INSTALLING CHART EQUIPMENT MUST COMPLY WITH THESE INSTRUCTIONS, PRACTICES, AND PROCEDURES ALONG WITH ANY LIFTING AND HANDLING AND OTHER INSTRUCTIONS, PRACTICES, AND PROCEDURES PROVIDED WITH INDIVIDUAL UNITS.

I. INTRODUCTION

A. Configuration

B. Codes and Materials of Construction

I. A. CONFIGURATION

I. A. Configuration (see Figure I, inside cover)
Chart BAHX are constructed of aluminum. The basic construction consists of layers of corrugated fins which are furnace brazed between parting sheets. The BAHX dimension created by this stack of layers is referred to as the stack height dimension of the BAHX.

The rectangular plate-fin "block" created by this stack of layers is also referred to as a "core" and is normally specified by its outside block dimensions of "W" (width) times "H" (stack height) times "L" (length). A BAHX's size, number of layers, type of fins, stacking arrangement, and stream circuiting will vary depending on the application requirements.

The basic components of a brazed aluminum heat exchanger are described below in sections I. A. 1 through 1. A. 10. Sections I. A. 11 through I. A. 15 define the terminology used to describe the Chart heat exchanger assemblies and associated piping.

I. A. 1. Nozzles
Nozzles are the pipe sections used to connect the BAHX headers to the customer piping.

I. A. 2. Headers
Headers are the half cylinders that provide for the distribution of fluid between the nozzles and the ports of each appropriate layer within the BAHX.

I. A. 3. Ports
Ports are the openings in either the side bar or the end bar, located under the headers, through which the fluids enter or leave individual layers.

I. A. 4. Distributor Fins
Distributor fins distribute the fluid between the port and the heat transfer fins. The distributor fin used adjacent to a port is called a port fin. The distributor fin used between a port fin and a heat transfer fin is called a turning fin.

I. A. 5. Heat Transfer Fins
Heat transfer fins provide an extended heat transfer surface. All fins, both heat transfer and distributor, provide a connecting structure between the parting sheets, thereby creating the essential structural and pressure holding integrity of the BAHX.

I. A. 6. Parting Sheets
Parting sheets (sometimes referred to as separator sheets) contain the fluids within individual layers in the BAHX and also serve as the primary heat transfer surface.

I. A. 7. Outside Sheets
Outside sheets (sometimes referred to as cap sheets) are the outermost parting sheets. They serve as the outer protective surface of the BAHX as well as a land for weld attachment of the headers.

I. A. 8. Side and End Bars
Side and end bars enclose individual layers and form the protective perimeter of the BAHX.

I. A. CONFIGURATION

I. A. 9. Support Angles

Support angles are typically 90° extruded aluminum angles welded to the BAHX bar face for the purpose of supporting or securing a BAHX in its installed position. Other support configurations, such as pedestal bases, are also available (see Figure XI).

I. A. 10. Lifting Lugs

Lifting lugs are lift attachment points strategically located and welded to the BAHX bar face or a header/nozzle assembly for the specific purpose of lifting the BAHX into its installed position.

I. A. 11. Modular BAHX Assembly

A modular BAHX assembly consists of two or more individually brazed BAHX blocks that are welded together prior to attaching the headers to form a single piece BAHX. This form of construction is used when the customer's heat exchange requirements exceed the maximum block size that can be furnace brazed. Modular construction eliminates the need for costly piping to interconnect separate, individual BAHX.

I. A. 12. Multiple BAHX Assembly

A multiple BAHX assembly, often referred to as a "battery," consists of two or more BAHX piped or manifolded together into a single assembly with the individual BAHX arranged either in a parallel, series, or combination parallel series arrangement. Multiple BAHX assemblies are used when the customer's heat transfer requirements are too large for either single piece or modular BAHX construction.

I. A. 13. Cold Box

A cold box consists of a welded airtight carbon steel casing, usually rectangular in shape, which supports and houses BAHX, piping, other related cryogenic equipment, and insulation material. More information can be found in the Cold Box Installation, Operation, and Maintenance Manual.

I. A. 14. Transition Joint

A transition joint is a bimetallic coupling used to make the transition from aluminum to stainless steel piping. Transition joints are available in various configurations.

I. A. 15. Core-in-Kettle® Assembly

A Core-in-Kettle® assembly consists of a cylindrical pressure vessel, usually carbon or stainless steel, which contains and supports one or more BAHX and associated piping including transition joints. In operation, one fluid is piped through the headered stream of the BAHX and the other partially fills the vessel and communicates with the open (unheadered) stream of the BAHX.

I. B. CODES AND MATERIALS OF CONSTRUCTION

I. B. Codes and Materials of Construction

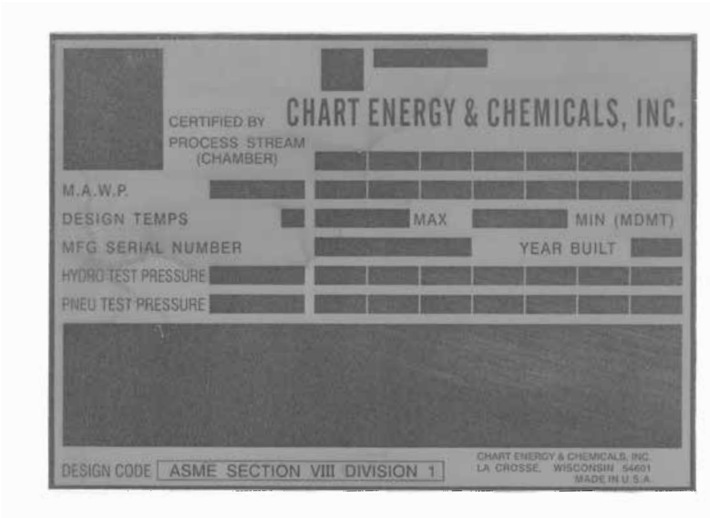
Chart BAHX are normally designed and manufactured in accordance with Section VIII, Division I of the ASME Pressure Vessel Code, carry the "U" stamp, and are registered with the National Board of Boiler and Pressure Vessel Inspectors. Associated piping is normally designed and manufactured in accordance with the ASME B31.3 Piping Code. The ASME pressure vessel and piping code boundaries are indicated on the Chart drawing.

Chart BAHX and piping are sometimes designed and manufactured to other (international) codes. The governing international code is specified on the Chart drawing and BAHX nameplate.

The following table indicates the typical materials of construction for the BAHX components.

FIGURE III

Typical BAHX Nameplate



COMPONENT	TYPICAL MATERIALS (Aluminum Alloy)
Outside Sheets	3003
Parting Sheets	3003
Side and End Bars	3003
Heat Transfer Fins	3003
Distributor Fins	3003
Headers & Nozzles	5083*
Flanges	6061-T6*
Support Angles	6061-T6*
Lifting Lugs	5083*

*Actual materials may differ and are specified on the Chart assembly drawing.

II. INSTALLATION

A. Arrival Inspection

B. Storage

C. Lifting and Handling

D. Mounting, Bracing, and Shipping Support

E. Pipe Connections

F. Venting

G. Insulation

H. Instrumentation

I. Smart Layers®

II. A. ARRIVAL INSPECTION

II. A. Arrival Inspection

Upon arrival, verify the nameplate matches the purchase order. The BAHX should be inspected for shipping damage and contamination. Closely examine all units for external damage. For units shipped unpressurized, check under the shipping covers for contamination of the port openings. For units shipped pressurized (normally to 15 psig [1 barg]) with dry air or nitrogen, each headered or manifolded stream is provided with a valve and coupling to which a pressure gauge can be mounted (see Figure XII). A positive pressure should be indicated on the gauge when the valves are opened. If a stream does not indicate a positive pressure and the valve and coupling connections have been checked for leakage, it should be repressurized with dry air or nitrogen to 15 psig (1 barg). If a leak in the BAHX, shipping damage, or internal shipping contamination is confirmed, contact Chart for further direction.

II. B. STORAGE

II. B. Storage

An indoor storage area away from any main work area is recommended. Indoor storage is required for BAHX having open layers or nozzles not covered with welded or bolted covers. Any ingress of moisture into these open layers should be avoided. In all storage areas, the following additional recommendations should be followed.

II. B. 1.

BAHX are typically shipped on wood or steel channel skids. Skidded BAHX may also be packaged in a wooden crate or metal shipping container. Do not stack skidded or crated BAHX.

BAHX should be stored in the original packaging, which is generally suitable for three years. For longer term storage, consideration should be given to special packaging. Consult Chart for packaging options.

II. B. 2.

The storage area should provide level, uniform support with good drainage.

If the BAHX has been removed from its packaging, it should be laid on wooden sleepers in a horizontal position on the outside sheet face of the BAHX. The wooden sleepers should be at least 6 inches (152 mm) wide and extend beyond the edges of the BAHX. Failure to extend sleepers beyond the edges of the BAHX can result in internal damage to the outside layers. Use only two sleepers – one near each end of the BAHX – at a distance from each end that is approximately one fourth the BAHX's length. Avoid positioning the sleepers under any headers. Use a soft, resilient material such as fiber board as a buffer between the sleeper and the BAHX.

II. B. 3.

The storage area should be located where the BAHX is not subjected to fluids or atmospheres that are corrosive to aluminum.

II. B. 4.

The storage area should be located where the BAHX is not subjected to vibration.

II. B. 5.

Avoid a location where other work activity or falling objects will be in the vicinity of the stored BAHX. External denting of the BAHX can damage the internal matrix of the BAHX and cause leakage.

II. B. 6.

Avoid a location that is subject to large fluctuations in temperature (especially below 32 °F [0° C]), or high humidity when the BAHX is not sealed and weather-proofed, as this can cause condensed water to accumulate in the BAHX and freeze when the BAHX is placed in storage or operation. Water freezing inside the BAHX can damage its internal matrix.

NEVER STACK BAHX. STACKING OF BAHX COULD RESULT IN A BAHX FALLING FROM ITS STACKED POSITION WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

II. B. STORAGE

II. B. 7.

BAHX must be properly covered and sealed in such a manner that dirt, sand, water, or foreign materials cannot enter open nozzles, ports, or through any other access into the BAHX. For BAHX that are shipped pressurized, dry air or nitrogen with a dew point of 32 °F (0 °C) or less should be sealed in each stream during storage. The dry air or nitrogen pressure should be 15 psig (1 barg), or one third the stream design pressure, whichever is less. The BAHX should be checked periodically to ensure that the pressure is maintained.

For BAHX that are not shipped with pressure and do not have welded shipping covers on the nozzles, all nozzle openings on the BAHX should be covered and sealed while the unit is in a dry condition.

FAMILIARIZATION WITH ALL APPLICABLE CHART DRAWINGS IS REQUIRED BEFORE ANY INSTALLATION WORK PROCEEDS. PARTICULAR CARE SHOULD BE TAKEN WHENEVER OFF-LOADING, MOVING, OR LIFTING THE BAHX.

FAILURE TO HANDLE EQUIPMENT PROPERLY COULD RESULT IN THE BAHX BEING DROPPED OR SOME OTHER EQUIPMENT ACCIDENT WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

II. C. LIFTING AND HANDLING

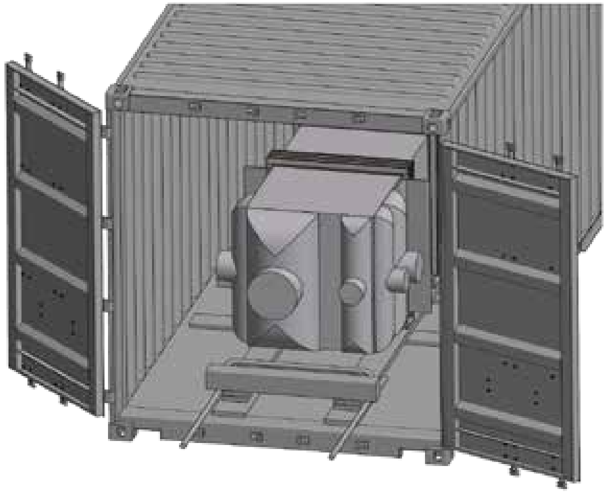
II. C. Lifting and Handling

Review lifting drawings that ship with each unit. Confirm the weight, dimensions, and lift connection locations of the BAHX. Select the appropriate hoisting machines, spreader beams, slings, shackles, and other material handling tools in consideration of the height, the BAHX weight, and the angle and direction of the hoisting. Care should be taken to avoid impacts to the BAHX. Rough or improper handling can cause damage to the internal matrix of the BAHX.

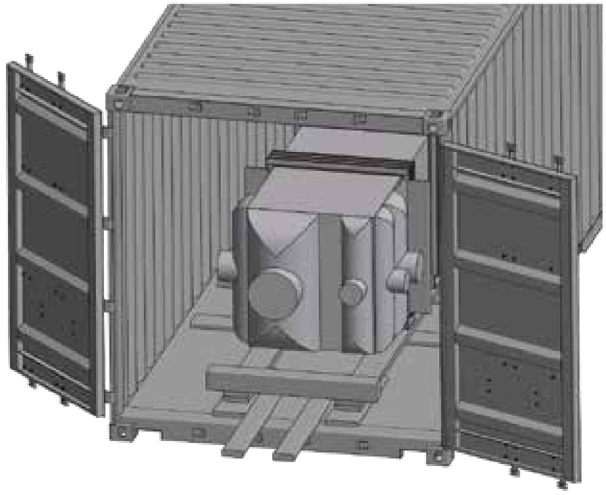
BAHX may be removed from metal shipping containers by towing with a chain, cable, or fork lift (see Figure IV). Only tow from the indicated end of the skid, do not tow from any part of the BAHX.

FIGURE IV

Removing BAHX from metal shipping containers



Chain or cable method



Fork lift method

II. C. LIFTING AND HANDLING

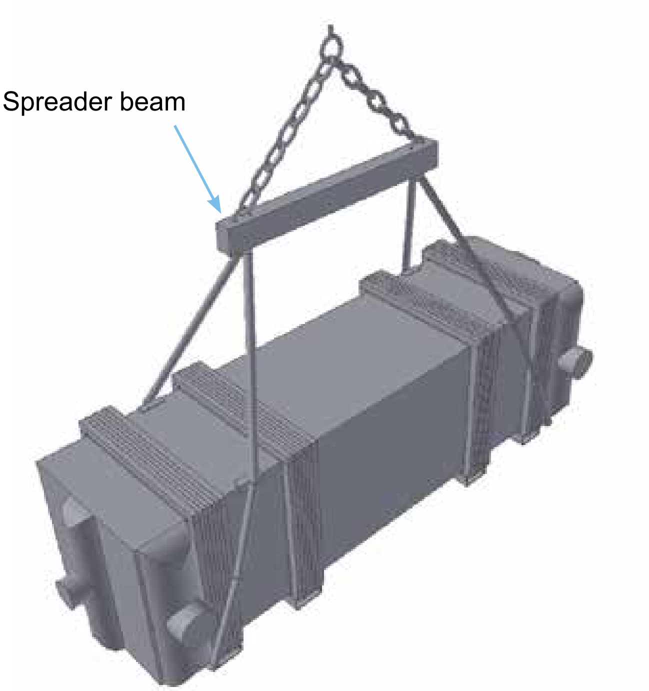
II. C. 1. Single BAHX

II. C. 1. a. Crated or Skidded (Lifting and Moving in a Horizontal Position)

It is preferred to lift the exchanger with a crane. Crated or skidded BAHX should be lifted with a crane or hoist by using slings and a spreader beam (see Figure V). Use nylon slings or polyester rope with scuff angles to protect the exterior of the BAHX (see Figure VI). Wood skidded or crated BAHX can be towed with a fork truck , but do not tow steel channel skidded BAHX. If a forklift is used ensure adequate protection against the aluminum and the forks extend full width of the BAHX.

FIGURE V

Horizontal lifting and moving instructions (Steel channel skidded BAHX)

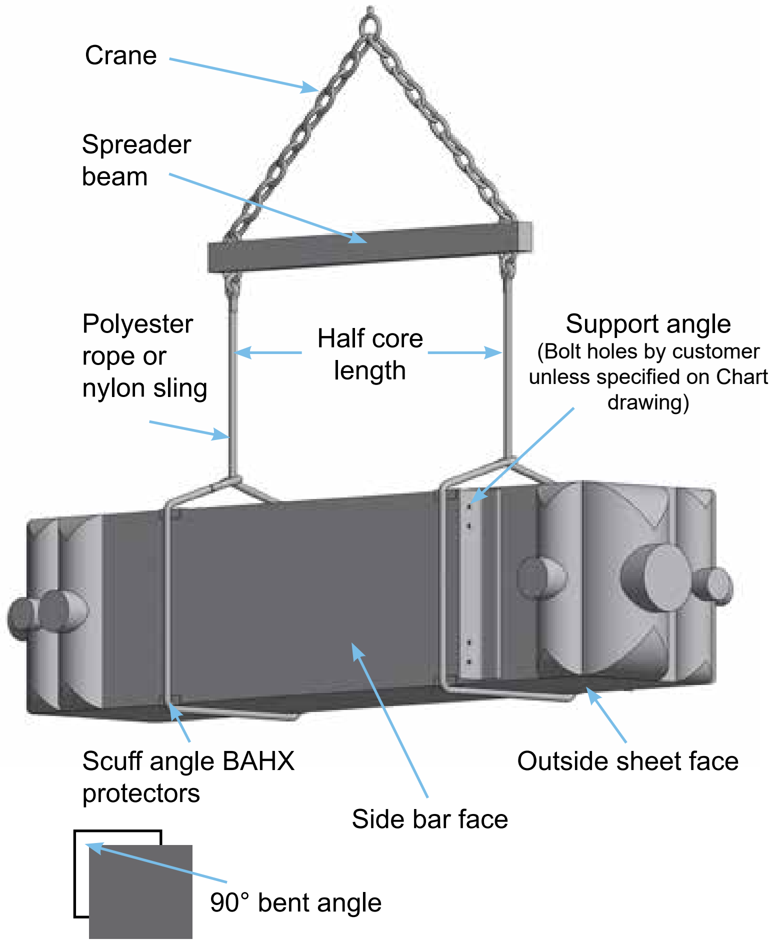


Sling method

II. C. LIFTING AND HANDLING

FIGURE VI

Horizontal lifting and moving instructions (Unpackaged BAHX)



II. C. 1. b. Unpackaged (Lifting and Moving in a Horizontal Position)

Do not use cables directly on the exterior of the BAHX as they can dent or cut into the exterior of the BAHX and cause damage to its internal matrix. Scuff angles are 90° angles placed on the corners of the BAHX under the sling or belt.

II. C. 1. c. Rolling to Alternate Side

Rolling of the BAHX from the shipping attitude is permitted when specified on the Chart assembly drawing. When permitted, a rolling instruction is shipped with the BAHX.

II. C. 1. d. Rotating and Lifting to a Vertical Position

The method for lifting a BAHX from its horizontal shipping position to the vertical installation position will depend upon BAHX configuration and weight. Lifting instructions are provided on the Chart drawings shipped with the unit.

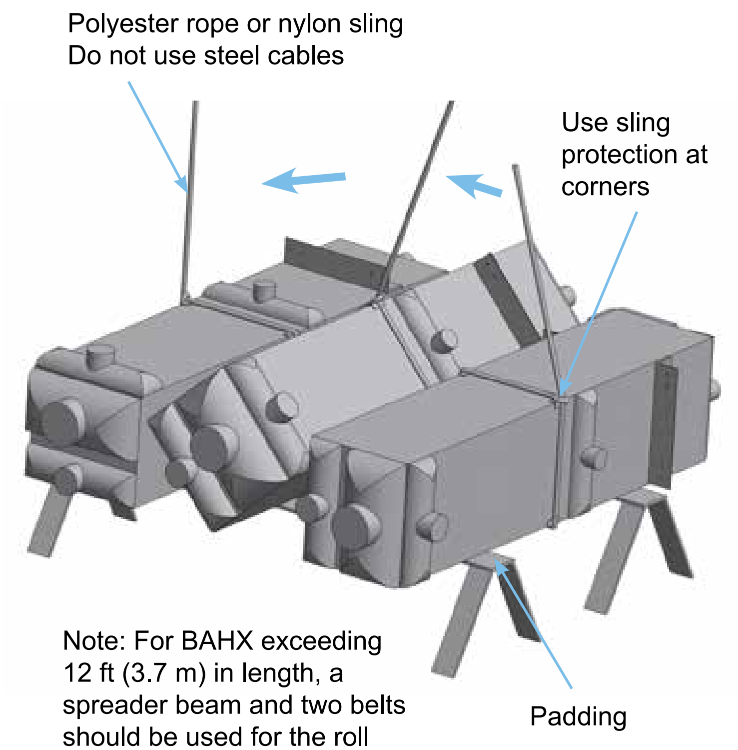
LIFT DIRECTLY FROM THE BAHX BLOCK ITSELF. DO NOT LIFT FROM ANY HEADER, NOZZLE, OR PIPING UNLESS SPECIFICALLY INDICATED ON THE CHART DRAWING.

FAILURE TO HANDLE EQUIPMENT PROPERLY COULD RESULT IN THE BAHX BEING DROPPED OR SOME OTHER EQUIPMENT ACCIDENT WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

II. C. LIFTING AND HANDLING

FIGURE VII

Typical method for rolling BAHX from shipping attitude to alternate sides (Unpackaged BAHX)
Use only when authorized on Chart assembly drawing.



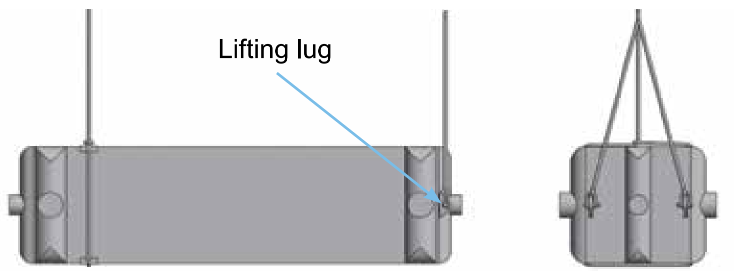
IF LIFTING LUGS ARE PROVIDED, THEY SHOULD BE USED AS THE ATTACHMENT LIFTING POINT. IF LIFTING LUGS ARE NOT PROVIDED, AND SPECIFIC LIFTING INSTRUCTIONS FOR THE UNIT ARE NOT AVAILABLE, CONTACT CHART. DO NOT LIFT USING THE NOZZLES OR ANY OTHER PIPING UNLESS SPECIFICALLY SHOWN IN THE CHART DRAWING FOR THE UNIT.

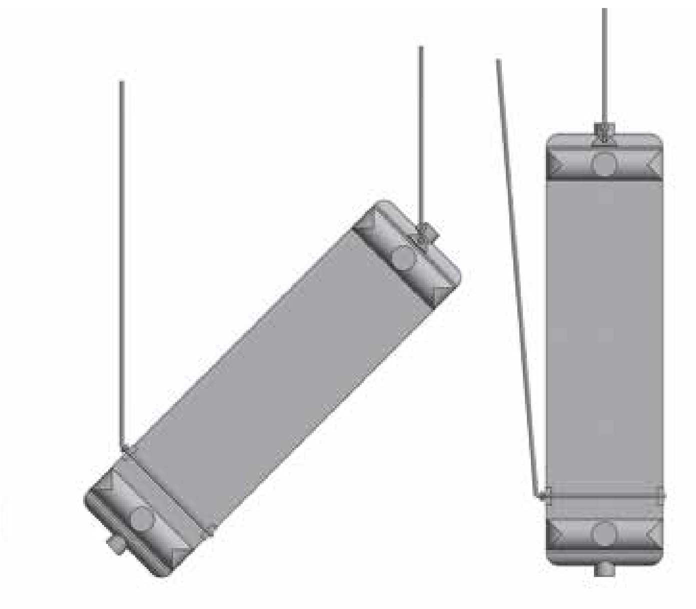
There are two basic methods for lifting to the vertical position. Other methods are approved only if specified on the Chart drawing for the unit. Both methods are similar except for the point of lifting attachment.

One method involves the use of lifting lugs provided with the Chart unit (see Figure VIII).

FIGURE VIII

Typical method lifting BAHX to vertical position using provided lifting lugs.



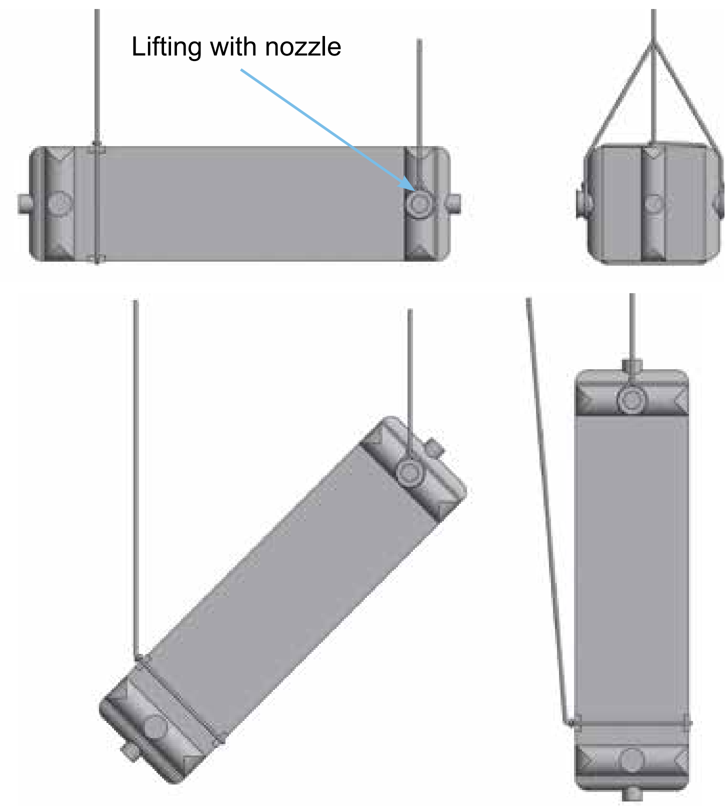


II. C. LIFTING AND HANDLING

The other method involves lifting using the BAHX nozzles (see Figure IX). These lifting methods are used for both support angle mounting and pedestal base mounting of BAHX.

FIGURE IX

Typical method lifting BAHX to vertical position using nozzles on the BAHX



II. C. 2. Multiple BAHX Assemblies

Considering the numerous possible variations in BAHX and piping assembly configurations, size, and weight, a single lifting, handling, and erection procedure for multiple BAHX assemblies is not possible.

For these assemblies, lifting instructions are included on the Chart assembly drawing or on a separate erection drawing. Multiple BAHX assemblies should be handled with the same care afforded individual BAHX.

II. C. 3. Core-in-Kettle® Assemblies

Core-in-Kettle® assemblies are either provided with appropriate lifting lugs on the kettle or instructions as to where to sling around the assembly.

WHEN LIFTING LUGS ARE PROVIDED ON CHART CORE-IN-KETTLE® ASSEMBLIES FOR LIFTING AND HANDLING THEY SHOULD BE USED WHENEVER MOVING THE CORE-IN-KETTLE® ASSEMBLY.

FAILURE TO HANDLE EQUIPMENT PROPERLY COULD RESULT IN THE BAHX BEING DROPPED OR SOME OTHER EQUIPMENT ACCIDENT WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

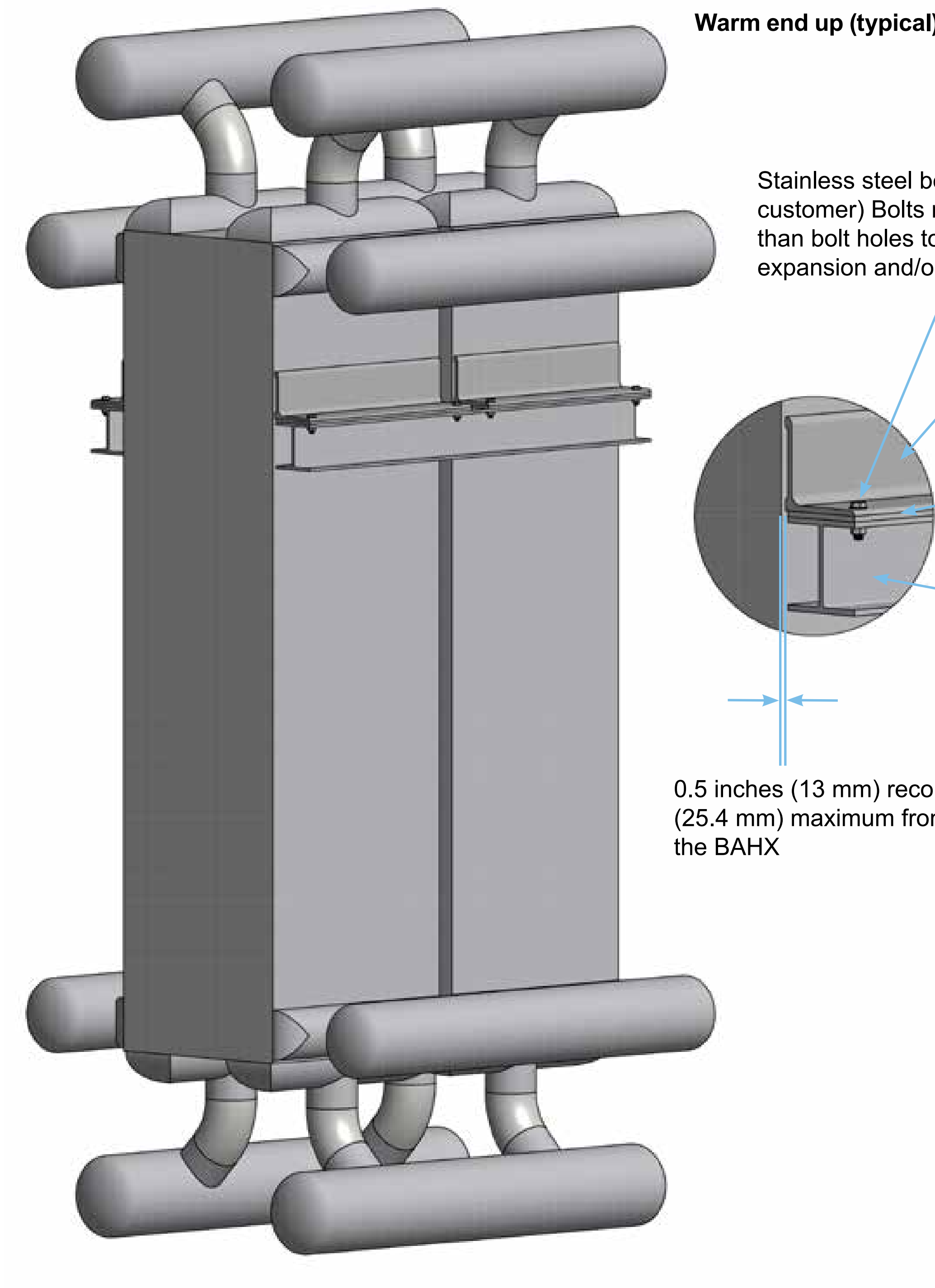
II. C. LIFTING AND HANDLING

FIGURE X

Typical support angle mounting system

(Single or multiple BAHX assemblies)

Warm end up (typical)



II. D. MOUNTING, BRACING, AND SHIPPING SUPPORT

II. D. Mounting, Bracing, and Shipping Support

II. D. 1. Support Angle Mounting System (Single or Multiple BAHX Assemblies)

Chart BAHX are normally installed vertically with the warm end up (see Figure X). Other orientations are permissible only if specified on the Chart assembly drawing. Chart BAHX are normally provided with aluminum support angles welded directly to the side bar face of the BAHX for mounting purposes.

The following are general mounting recommendations for both single BAHX and for multiple BAHX assemblies utilizing support angle mounting systems (see Figure X).

II. D. 1. a.

All shipping supports should be removed as shown on the Chart drawings. Extreme care should be taken to keep all steel working torches and flame-cutting tools at a proper distance from the aluminum BAHX in order to prevent severe damage to brazed joints and to the internal matrix.

II. D. 1. b.

The support angle surfaces on the BAHX are in plane within 0.06 inches/foot (0.5%). The mating support surface (by customer) should be a continuous member and be in plane to this same standard. Shimming is acceptable but is not preferred.

II. D. 1. c.

Since these BAHX are normally installed in cryogenic services, some method of insulating between the Chart aluminum support angles and the customer mating support surface is recommended.

A minimum of 0.5 inch (13 mm) thick piece of Micarta® (phenolic canvas base laminate) block is recommended for this purpose. The insulation material thickness should be sufficient to minimize heat leak and prevent frost spots from developing on the supports or cold box walls during operating conditions.

II. D. 1. d.

Provisions for thermal expansion and contraction of the BAHX in the horizontal plane at the support location must be provided.

The expected thermal movement should be calculated in both horizontal directions by the following equation:

$$\mathbf{D=12.6 \times 10^{-6} \times L \times \Delta T}$$

where L is the distance in inches between extreme bolts in the direction under consideration, ΔT is the change in temperature in °F at the support location from the installed (ambient) temperature to the coldest possible operating temperature, and D is the expected thermal movement in inches which will result from this calculation.

II. D. MOUNTING, BRACING, AND SHIPPING SUPPORT

If the expected thermal movement in both directions is 0.5 inches (13 mm) or less, the bolt hole diameters in the aluminum support angles should be oversized by adding the maximum expected thermal movement to the bolt diameter.

If the expected thermal movement exceeds 0.5 inches (13 mm) in one of the horizontal directions, a slotted hole should be used with a slot length equal to the bolt diameter plus the maximum expected thermal movement, and a slot width equal to the bolt diameter plus the expected thermal movement in the other direction.

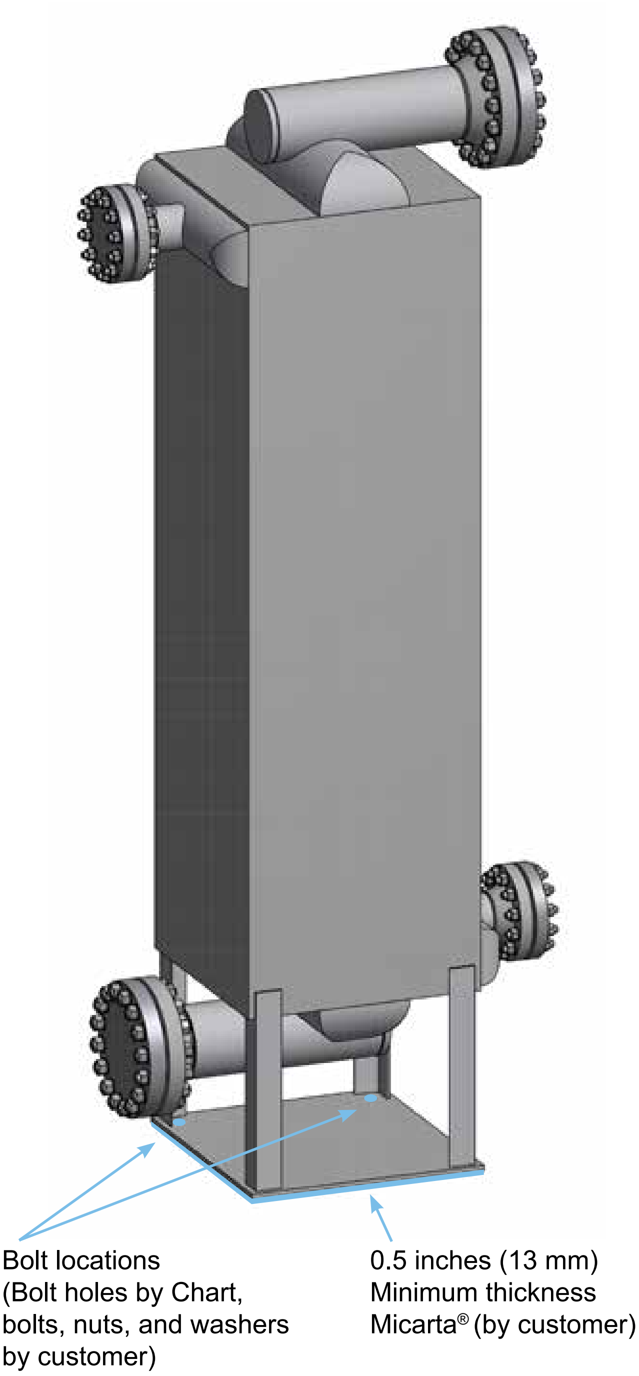
If the expected movement exceeds 0.5 inches (13 mm) in both directions, the holes in the aluminum support angles should be slotted as per above in one direction and the holes in the stainless steel support beam should be slotted as per above in the other direction with slot widths equal to the bolt diameter plus 0.12 inches (3 mm).

II. D. 1. e.

Bolts, nuts, and washers employed to secure the BAHX to the supporting surface must be stainless steel, and tightened to finger tight only (this requirement applies to both angle type and pedestal base type mounting systems). Do not use lock washers. Use a double nut or interrupt the bolt threads to prevent the nut from working loose. Wrench tightening the bolts could allow relatively small horizontal pipe loads applied to either end of the BAHX to develop bending moments on the BAHX which may produce unacceptable stress concentrations at the support angles.

FIGURE XI

Typical pedestal base mounting system
(Single or multiple BAHX assemblies)
Warm end up (typical)



II. D. MOUNTING, BRACING, AND SHIPPING SUPPORT

II. D. 1. f.

To avoid excessive bending moments on the support angle itself, the edge of the support surface must be no more than 1.0 inches (25.4 mm) from the BAHX side bar face. A distance of 0.5 inches (13 mm) is recommended (see Figure X).

II. D. 1. g.

The support system should be safeguarded by the provision of a sway brace, located at the opposite end of the BAHX away from the main support angles or pedestal base, whenever the total external loads (pipe, wind, and earthquake) are sufficient to cause lateral movement of the BAHX.

A close fit between the BAHX wear plate and the sway brace is required since changing from ambient to operating at cryogenic temperatures at this position can produce 0.12 inches (3 mm) of movement from thermal contraction. If requested, wear plates can be furnished on the BAHX by Chart.

Do not fasten any sway brace directly to the BAHX. The BAHX must be free to move in the vertical direction.

II. D. 1. h.

For reversing (air separation service) BAHX, supporting directly from the bottom (warm end) manifolds is acceptable if provided for on the Chart assembly drawing. Warm end manifolds for reversing BAHX should always be provided with sumps and drains of adequate size to return any condensed water from the manifold piping so that water will not be entrained in the fluid stream or slugged into the BAHX during pressure reversals.

II. D. 2. Pedestal Base Mounting System (Single or Multiple BAHX Assemblies)

An alternative method to the support angle mounting system is an aluminum pedestal base mounting system provided with the BAHX (see Figure XI). The pedestal base mounting system is generally employed when cold box installation is not required and the BAHX can be mounted at ground level as this is usually a less costly method for mounting.

The same recommendations regarding shimming, insulation, bolt hole size, bolt tightness, and bracing for support angle mounting systems in Section II. D. 1. should be followed for pedestal base mount systems.

II. D. 3. Core-in-Kettle® Assemblies

The holes for the anchor bolts are slotted in the sliding saddle to allow for thermal contraction and expansion. When installing a Core-in-Kettle® assembly it is critical to align the anchor bolts in the center of the slots. In rare cases the saddle geometry may require the anchor bolts be installed offset in the slots. In these cases the required positioning is specified on the Core-in-Kettle® assembly drawing.

II. E. PIPE CONNECTIONS

II. E. Pipe Connections

II. E. 1. Pipe Loads

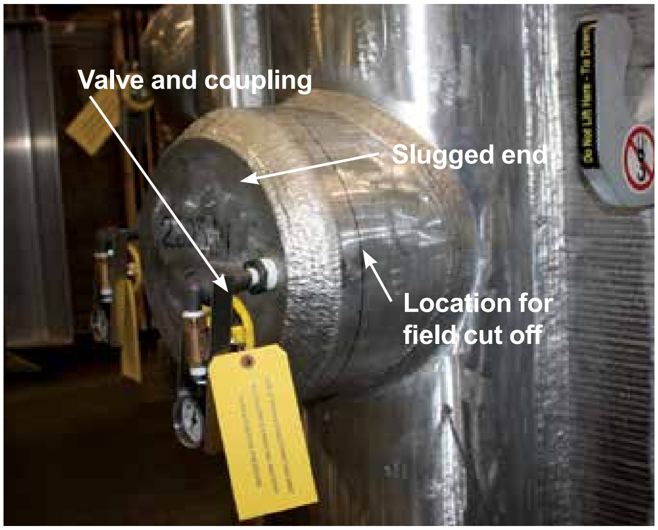
A table indicating maximum allowable pipe loads for the BAHX or assembly is provided with the Chart drawing. This table indicates the maximum allowable bending moment and the axial load that can be applied at each header location on the BAHX. These maximum loads are not to be applied simultaneously. Instructions for summing applied moments and forces are supplied with this table.

It is the customer's responsibility to provide sufficient piping flexibility or anchor points in the customer piping to ensure that the combined loads on each nozzle and on the BAHX are within the allowable limits specified by Chart.

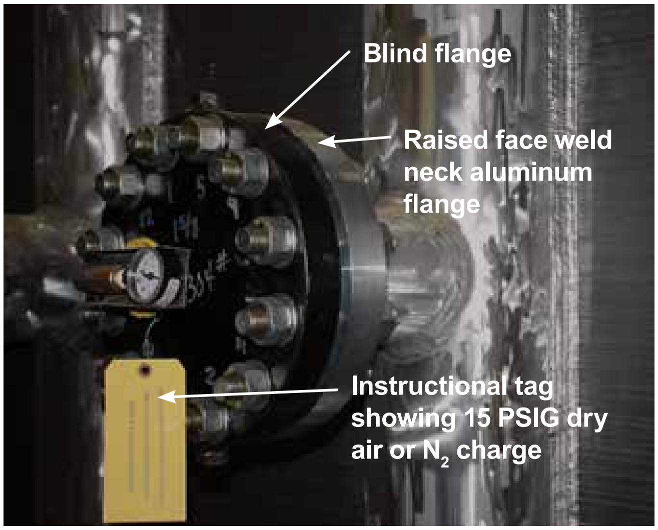
FAILURE TO PROVIDE SUFFICIENT PIPE FLEXIBILITY OR ANCHOR POINTS COULD RESULT IN COMBINED PRESSURE AND EXTERNAL PIPE LOADS BEING APPLIED WHICH EXCEED THE ALLOWABLE LOADS OF THE BAHX AND MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

FIGURE XII

Typical connections for BAHX and assemblies shipped with pressure



Typical slugged connection



Typical flanged connection

II. E. PIPE CONNECTIONS

Prior to removing the plug or pressure gauge from the shipping valve, be sure the valve is in the closed position. Exercise caution and accepted safety procedures for removal of a plug from a pressure vessel.

FAILURE TO CONFIRM THE SHIPPING VALVE IS IN THE CLOSED POSITION PRIOR TO REMOVAL OF THE PLUG OR PRESSURE GAUGE CAN RESULT IN THE PLUG OR GAUGE BECOMING A PROJECTILE WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

II. E. 2. Connection Configurations

II. E. 2. a. Slugged Connections

The proper cut off location of the nozzle or pipe can be found on the Chart assembly drawing (see Figure XII). Beveling and welding procedures must be followed per the applicable code requirements. Before making final connections to the BAHX, care should be exercised to remove any saw chips, torch slag, or other foreign material from the pipe, nozzle, and header area. These items can plug the BAHX.

II. E. 2. b. Flanged Connections

Aluminum or steel (stainless for cryogenic service) mating flanges are typically used with the Chart flanged connection.

Care should be exercised to protect the machined face of the flange against scratches, dents, and other damage that will reduce the effectiveness of the gasket in making a proper seal.

The two mating surfaces of the flanges should be parallel with each other prior to connecting. Flange faces must be aligned to the design plane to within 0.06 inches/foot (0.5%) maximum, measured across the diameter of the flange mating face, and flange bolt holes must be aligned to within 0.12 inches (3 mm) maximum offset.

Connections should be made by gradually tightening diametrically opposite bolt pairs and tightening the pairs in a sequence that uniformly loads the gasket. Installed bolts and gaskets shipped with the blind flange must not be used for making final connections as they are not designed for cryogenic service. Stainless steel bolts and nuts must be used for the final field connection for cryogenic service. Stainless steel washers must be used under the bolt heads or nuts on the aluminum flange, and threads should be lubricated for proper torque wrench applications.

II. E. PIPE CONNECTIONS

Gasket Recommendations For Use With Aluminum Flanges:

Chart recommends Flexitallic Flexpro gaskets or equivalent (m=2.0, y=2500 psi [17.2 MPa]). If stainless steel spiral wound gaskets are used, Chart recommends they be low seating stress such as Flexitallic LS (m=3.0, y=5000 psi [34.5 MPa]). If higher seating stress gaskets are selected consult Chart to determine if Chart's standard recommended bolt torques are adequate.

Bolting recommendations:

	Down to -50 °F (-45 °C)	Below -50 °F (-45 °C) Stud Diameters thru 1.5 inches (38 mm)	Below -50 °F (-45 °C) Stud Diameters above 1.5 inches (38 mm)
Studs	SA193 B7	SA320 B8 CL2	SA193 B8M2
Nuts	A194 GR 2H	SA194 GR 8	SA194 GR 8

Recommended Bolt Torques:

All bolting must be given a final tightening by torque wrench. Bolts are to be torqued to the full value shown in the table below and then re-torqued after 15 minutes. Torque values are based on a resultant bolt stress of 30,000 psi assuming well lubricated studs, nuts, and washers.

Bolt torques for use with flanges:

Bolt Size (in)	TPI	Torque (ft-lbs)	Torque Increments
1/2	13	30	Snug, then full torque
5/8	11	60	
3/4	10	100	
7/8	9	160	Snug, 1/2 torque, then full torque
1	8	245	
1-1/8	8	355	
1-1/4	8	500	
1-3/8	8	680	
1-1/2	8	800	Snug, 1/3 torque, 2/3 torque, then full torque
1-5/8	8	1100	
1-3/4	8	1500	
1-7/8	8	2000	
2	8	2200	Snug, 1/4 torque, 1/2 torque, 3/4 torque, then full torque
2-1/4	8	3180	
2-1/2	8	4400	
2-3/4	8	5920	
3	8	7720	

II. E. 2. c. Weld Prepared Connections

Weld prepared connections are properly trimmed to length and beveled for welding. The trim length and beveling detail is provided on the Chart drawing. Connections prepared for welding are covered during shipments. The BAHX or assembly does not ship with pressure.

Beveling of the mating pipe and welding procedures must be per the applicable code requirements. Before making final connections to the BAHX, remove any saw chips, torch slag, or other foreign material from the pipe, nozzle, and header area. These items can plug the BAHX.

II. E. PIPE CONNECTIONS

II. E. 3 Transition Joints (see Figure XIII)
Unless authorized by the joint manufacturer, transition joints are to be attached only to piping components.

To prevent failure of the bond during welding, precautions must be taken to avoid overstressing the bond due to differential expansion between the aluminum and stainless steel joint components. These stresses can be maintained within allowable limits by taking the following precautions:

- Place a chill block or damp rags on the aluminum/steel overlapping bond area. If damp rags are used, care should be taken to keep the rags or cloths damp. A dry cloth will allow the joint to become excessively hot. Temperature in the aluminum/steel overlapping area must be held to a maximum of 300 °F (149 °C), unless higher temperatures are permitted by the joint manufacturer.

- When installing a loose transition joint, weld the stainless steel end first whenever possible. This will provide a larger sink for the heat generated by the aluminum welding.

- Use weld techniques and sequences to minimize the heat input.

- Care should be taken to avoid non-uniform heating, weld sequences, or weld techniques that would cause isolated high stress areas, i.e. “Block Welding,” local repair welds, or other similar types of localized welding.

FIGURE XIII

Typical transition joints for piping connections

Photo courtesy of Groupe RBDH

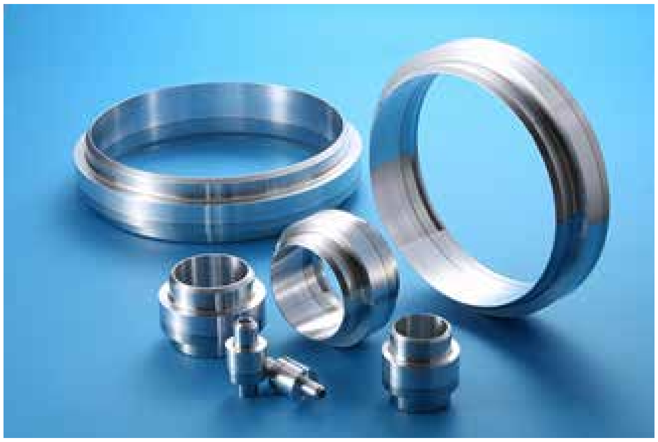


Photo courtesy of Asahi Kasei Corporation

II. F. VENTING

II. F. Venting

External venting of inactive or non-operational internal zones of some BAHX is required when specified on the Chart drawing. Examples of inactive zones that require venting are:

• the modular space formed by welding together two BAHX blocks.

• the dead corner of a reversing stream warm end distributor employing the slant bar drainability feature.

• the space formed between two tandem streams having adjacent side headers at mid BAHX.

• other special cases.

Chart BAHX that have an inactive zone are normally designed to be self venting and simply require that the plastic shipping plugs be removed just prior to insulating and pressurizing any stream. This requirement is stated on the Chart drawing and on a tag attached to BAHX.

If you wish to monitor an inactive zone by attaching a vent line, be sure to extend the vent line outside the cold box or insulation and provide a relief valve on the vent line to protect the inactive zone of the BAHX against pressurization over 15 psig (1 barg). Maintain the vent line in an internally frost free condition to eliminate the possibility of line blockage from freezing liquids. A 3/4” NPS (20DN) or larger line is recommended to avoid potential flow restriction.

FIGURE XIV

Vent plug tag

FAILURE TO LIMIT THE PRESSURIZATION OF INACTIVE ZONES IN THE BAHX TO A MAXIMUM OF 15 PSIG COULD RESULT IN A RUPTURE OF THE BAHX WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

II. G. INSULATION

II. G. Insulation

Since BAHX usually operate at cryogenic temperatures, highly efficient insulation should be applied by the customer to minimize heat leak. Insulation material is normally applied after the unit is installed at the job site. Flammable materials should be avoided for insulation. Insulation materials are not normally applied to the BAHX prior to installation because insulation materials are easily damaged in transit, they restrict the use of shipping tie downs and supports, and they would impair accessibility to the unit for lifting, mounting, leak testing, and other installation preparations.

When the BAHX is not mounted inside a cold box, the BAHX's exterior is normally insulated with rigid polyurethane foam, or other alternatives such as Foamglass® insulation, according to the thickness and requirements specified by the engineering contractor. These insulations are positioned and fastened around the BAHX and covered with a vapor barrier. Protective metal coverings or flashing can be used for this purpose.

In all installations, some form of insulation such as a Micarta® spacer should be used between the BAHX support member and the supporting beam or platform (see Section II. D. 1. c.).

Caution should always be exercised whenever welding or flame cutting near insulation materials.

Refer to the Cold Box Installation, Operation, and Maintenance Manual for instructions on insulating BAHX installed in cold box assemblies.

II. H. INSTRUMENTATION

II. H. Instrumentation

Proper instrumentation must be installed to properly operate BAHX within the guidelines (see Section III. C.).

Fluid temperatures and pressures should be monitored at the inlet and outlet of every stream at intervals of 1 minute. For boiling streams in reboiler services external to the column, a dedicated differential pressure instrument should be used to monitor for pressure oscillations indicating unstable flow. Fluid flow rates should be monitored with flow meters, or approximated with valve positions, pressure drop, or vessel liquid levels, at intervals of 1 minute. Fluid composition should be measured and logged at intervals of 1 month at a minimum or as frequently as the composition changes.

If desired, core block temperature can be directly measured using temperature devices installed by Chart.

Gas detectors should be installed in the vicinity to alert if any external leaks exist.

II. I. SMART LAYER®

II. I. 1. Smart Layer®

Smart Layer is a warning system comprised of inactive layers located on the outside of the stack that have been designed and proof tested for the full design pressure of the adjacent process stream(s). They are equipped with connections for a pressure monitor, pressure relief valve, and a Nitrogen charging port. The purpose of Smart Layer is to alert operators when a critical threshold of thermal stress damage has occurred, prior to any external leak occurring.

Smart Layer is an optional feature not included on all designs. The nameplate will indicate if a unit is equipped with Smart Layer.

II. I. 2. Function

Smart Layer functions by accumulating thermal stress damage faster than other parts of the BAHX. When a critical threshold of damage has accumulated, it will result in an “indication leak” in the Smart Layer. The indication leak is part of the intended function of Smart Layer, and will not cause any process fluids to leak to atmosphere. When an indication leak occurs, the DCS will signal the operator that a Smart Layer alarm has been activated.

II. I. 3. Smart Layer Hardware

Typical hardware includes a pressure transmitter to monitor the Smart Layer pressure, a pressure relief device that vents either to atmosphere or to flare, and a connection for charging and draining the Smart Layers

II. I. 4. Smart Layer Field Installation

Smart Layer is shipped with temporary shipping blinds. The balance of the Smart Layer components supplied by Chart (if any) are shipped loose to reduce the risk of damage during transport. After the BAHX has been installed, remove the temporary shipping blinds and install the Smart Layer components. Fill the Smart Layer with nitrogen to a charge pressure as described below. Smart Layer is not intended to be connected to a continuously regulating nitrogen system. Soap bubble test all Smart Layer connections to ensure leak tightness.

II. I. 5. Smart Layer® Charge Pressure Setpoint

Charge Smart Layer’s nitrogen blanket to a level sufficient to allow for proper operation of the PSV. The Charge pressure must also be set between the high and low level alarms described below.

II. I. 6. Smart Layer® High-Level Alarm Setpoint

Set the high level alarm below operating pressure of the stream(s) designated in the Smart Layer notes on the General Assembly Drawing. Ensure there is a measurable pressure difference between the charge pressure and the high level alarm.

II. I. 7. Smart Layer® Low-Level Alarm Setpoint

The low-level alarm setpoint is slightly above atmospheric pressure. The charge pressure will decrease during cool down. Ensure this pressure decrease will not trip the low level alarm.

FAILURE TO INSTALL THE SMART LAYER PRESSURE RELIEF VALVE MAY RESULT IN OVER PRESSURIZATION OF THE SMART LAYER WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

II. I. SMART LAYER®

II. I. 8. DCS Integration

The pressure transmitter should be connected to the plant DCS to record and monitor the Smart Layer pressure. Pressure should be recorded (typically at 1 minute intervals) to aid in root cause analysis in the event of a Smart Layer alarm.

II. I. 9. Smart Layer® Alarm

The DCS should be configured to alarm the operator if the Smart Layer pressure drops below or rises above the Alarm setpoints. A Smart Layer alarm is triggered by an indication leak in Smart Layer and signifies one or more stress cracks have occurred in the BAHX. This is most likely thermal fatigue damage caused by operation outside of the IOM guidelines. Contact Chart for guidance if a Smart Layer alarm is received.

II. I. SMART LAYER®

High Level Alarm

A high level alarm indicates communication between the Smart Layer and the adjacent process stream(s). This is most likely due to a parting sheet crack.

Low Level Alarm

A low level alarm indicates communication between the Smart Layer and the atmosphere. This is most likely due a cap sheet crack, but may also be a result of a non-stress related leak through a gasket, fitting, or instrument.

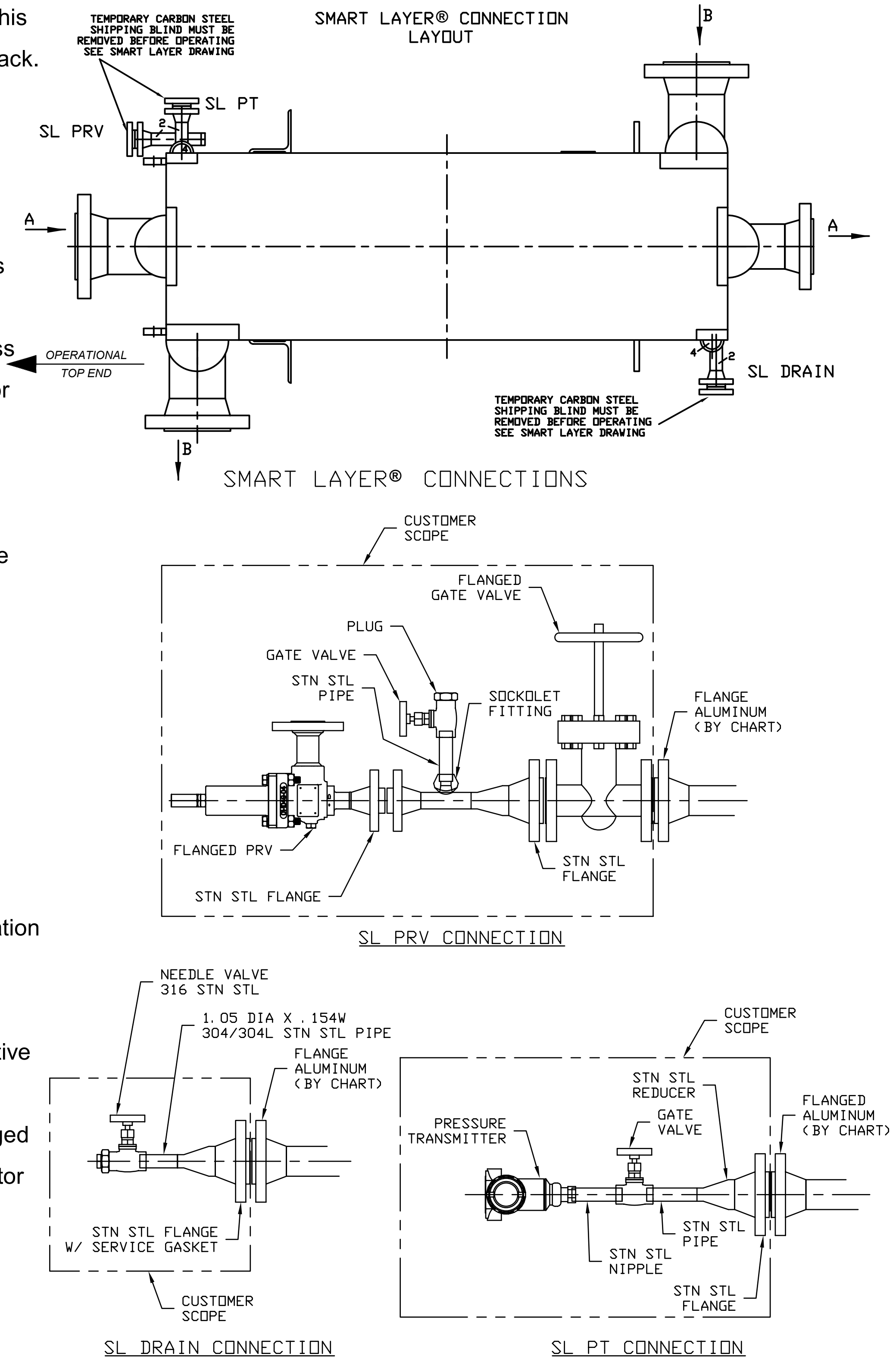
Maintenance

The Smart Layer pressure relief device and pressure transmitter should be included in the plant maintenance program.

Prior to shipping from the factory, the Smart Layer is leak tested to ensure a leak tightness sufficient to contain the Smart Layer charge pressure. After installation in the field, gasket degradation or differential thermal expansion may result in a persistent leak from Smart Layer to atmosphere that is not indicative of thermal stress damage. If this is the case, the Smart Layer may be recharged periodically to maintain function. Monitor the leak rate for changes that may indicate thermal stress cracking.

FIGURE XV

Smart Layer® Examples



III. TESTING AND OPERATION

A. Field Proof Testing

B. Fouling and Corrosion Protection

C. Startup, Operation, and Shut Down

D. Operating Records

III. A. FIELD PROOF TESTING

III. A. Field Proof Testing

Most codes require a pressure test of the piping system after the BAHX or assembly is installed. A pneumatic test is most often performed.

Only clean, dry gases should be used for pneumatic proof and subsequent leak testing. Water, or any fluid that may freeze under operating conditions, should not be used in any testing or cleaning of the Chart BAHX as it is extremely difficult to dry the BAHX in the field. Trapped water can freeze in the BAHX matrix and develop hydraulic pressures sufficient to rupture the internals of the BAHX without any external evidence. If water is accidentally introduced into the BAHX, see Section IV. C. 1. for drying procedures. In Section IV. B., several practical field tests are recommended for determining leaks.

The pneumatic proof test pressure must comply with National Board Inspection Code requirements or, if applicable, international pressure vessel code inspection requirements and must not exceed 1.1 times the maximum working pressure specified on the Chart nameplate.

OVERPRESSURIZATION OF THE BAHX COULD RESULT IN A RUPTURE OF THE BAHX WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

INTRODUCTION OF WATER TO ANY BAHX EXPOSED TO MERCURY CONTAMINATION CAN RESULT IN ACCELERATED CORROSION AND CAN CAUSE IRREPARABLE DAMAGE AND POTENTIAL CATASTROPIC FAILURE AND EXPOSE PERSONNEL TO HAZARDOUS AND UNSAFE WORKING CONDITIONS.

III. B. FOULING AND CORROSION PROTECTION

III. B. Fouling and Corrosion Protection

BAHX are capable of handling a wide variety of fluids. Fluids should be clean, dry, and non-corrosive to aluminum. Fluids containing particulate matter, waxy components, or corrosive elements should not be used in the BAHX.

III. B. 1. Filtering

The presence of particulates in the process streams may not only lead to BAHX plugging and fouling, but may also cause erosion in the high velocity areas of the BAHX. Fouling of the BAHX can be detected by a gradual or sudden increase in pressure drop and a loss of heat transfer performance.

All connecting pipelines carrying BAHX fluids should be thoroughly cleaned of all pipe scale, dirt, sand, and other debris before placing the BAHX in service.

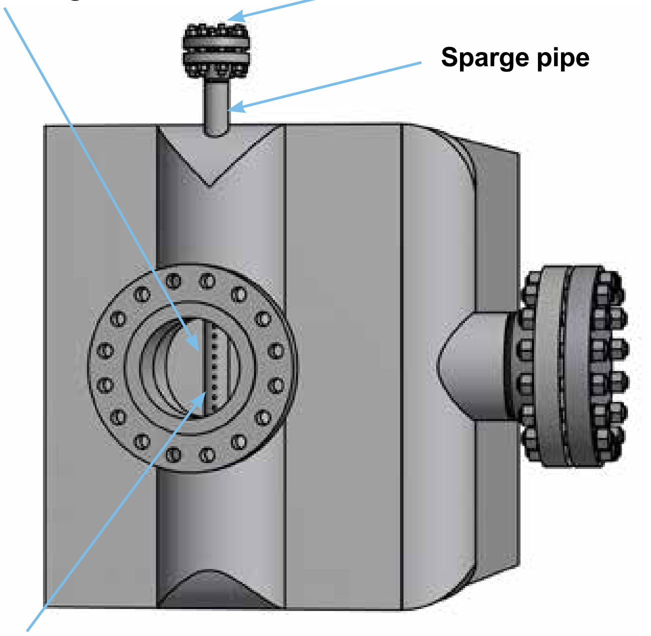
All streams should be filtered with a 177 micron (80 Mesh Tyler Standard) screen or finer, directly upstream of the BAHX, BAHX assembly or cold box. The filters should remain in place at all times while the BAHX is operating. The user should consider a dual filter system with sufficient valving to allow a filter to be changed without shutting down. Heavy duty, cleanable filters or strainers are recommended.

III. B. 2. Hydrate Suppression (Methanol Injection)

During startup, upset, or even normal operating conditions, the presence of hydrates or heavy hydrocarbons in the feed or other streams may freeze in the BAHX at operating temperatures. These hydrates or heavy hydrocarbons may eventually block some or all of the layers in the BAHX.

FIGURE XVI

Typical methanol sparge system top view (warm end)



III. B. FOULING AND CORROSION PROTECTION

When complete shut down for deriming is undesirable (see Section IV. C. 1.) methanol injection can be used to remove hydrates during operation if the operating temperature is warmer than -170 °F (-112.2 °C) (methanol freezes at approximately -170 °F). This method of hydrate suppression involves injecting methanol into the process fluid upstream of the Chart BAHX. An aluminum sparge pipe injector can be provided for this purpose inside the header of the Chart BAHX (see Figure XVI). Methanol is injected into the incoming feed gas via this sparge pipe. The feed gas then carries the methanol into the BAHX.

If a methanol injection sparge system is not used for an extended period of time, the methanol should be purged from the piping to eliminate the potential for methanol corrosion. This can be accomplished by blowing dry air or nitrogen through the methanol piping. Drain holes on the underside of the sparge pipe are provided for draining purposes.

If hydrate contamination is an ongoing problem, any upstream equipment where water could enter the BAHX stream should be inspected for leaks.

III. B. 3. Corrosion Protection

Trace impurities of H_2S, NH_2, CO_2, SO_2, NO_2, CO, Cl and other acid-forming gases may cause corrosion when liquid water is present in the stream. Additionally, certain water acidity levels can cause corrosion of aluminum. To avoid corrosion, the pH level of the water condensate should be between 5 and 7.

Carefully guard against the ingress of water vapor or liquid, either during commissioning or similar plant events where the BAHX is vulnerable to water ingress (for example, during core repair involving removal of piping to the BAHX), or by process fluids containing water. If allowed to freeze, accumulated water in trapped areas of the BAHX can structurally damage the internals of the BAHX.

External surface corrosion can be avoided by keeping the externals of the BAHX under a dry environment during installation and operation. Such precautions will eliminate the potential for intergranular corrosion attack or stress corrosion cracking of the BAHX components.

Under certain conditions, mercury can corrode aluminum and therefore caution must be used when handling process fluids containing mercury. However, Chart BAHX have been successfully used with fluids containing mercury provided the proper equipment design and operating procedures are implemented.

If mercury is suspected or anticipated:

- BAHX should not be exposed to process fluids containing mercury concentrations greater than 0.1 $\mu g/Nm^3$. Above this limit, mercury guard beds should be installed and mercury tolerant features should be considered in the design of the exchanger.

- Below 0.1 $\mu g/Nm^3$, purchasers should consider using exchangers with mercury tolerant features and mercury guard beds because the same gas field can sometimes contain large variations in mercury levels over time.

III. C. STARTUP, OPERATION, AND SHUT DOWN

III. C. Startup, Operation, and Shut Down

Chart BAHX can be expected to provide many years of useful life when operated in strict accordance with the instructions, practices, and procedures outlined in this manual. The range of life can vary depending on the process design, how demanding the operating conditions are, and other factors. A typical useful life is 20 years or more.

FAILURE TO OPERATE WITHIN THE GUIDELINES MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

III. C. 1.

Prior to startup, purge and dryout procedures must be completed to remove moisture and heavy hydrocarbons which may freeze at cryogenic operating temperatures. A thorough dryout must be carried out at the commissioning and after every subsequent shutdown where moisture may reach the cryogenic equipment. A warm (70 to 100 °F) (21 to 38 °C) dry gas must be used to achieve adequate dryness. All dead legs in the piping must be drained and purged.

ALL OPERATING CONDITIONS MUST BE WITHIN THE SPECIFIED CHART NAMEPLATE LIMITS AND THE CHART SPECIFICATIONS FOR THE BAHX BEING OPERATED. THE MAXIMUM WORKING PRESSURE AND TEMPERATURES ARE SHOWN ON THE CHART NAMEPLATE AND THE CHART DRAWING (SEE FIGURE III).

THE BAHX MUST BE OPERATED AT PRESSURES THAT DO NOT EXCEED THE MAXIMUM WORKING PRESSURE FOR EACH STREAM ON THE CHART NAMEPLATE. THE BAHX MUST BE OPERATED AT TEMPERATURES WITHIN THE LIMITS OF THE CHART NAMEPLATE WORKING TEMPERATURES.

III. C. STARTUP, OPERATION, AND SHUT DOWN

EXCEEDING ANY OF THE MAXIMUM WORKING PRESSURES OR TEMPERATURES SPECIFIED ON THE CHART NAMEPLATE COULD RESULT IN A RUPTURE OF THE BAHX WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

III. C. 2.

Appropriate pressure relief valves with settings below the Chart nameplate maximum working pressures must be provided by the user.

III. C. 3.

As with any pressure containing equipment, stresses in each component of a BAHX must be maintained within allowable limits during operation. Pressure loads, externally applied loads (e.g. piping forces and moments), and thermally induced loads each produce stress in the components. The resultant stress from these loadings must be controlled within allowable limits to prevent component damage or failure.

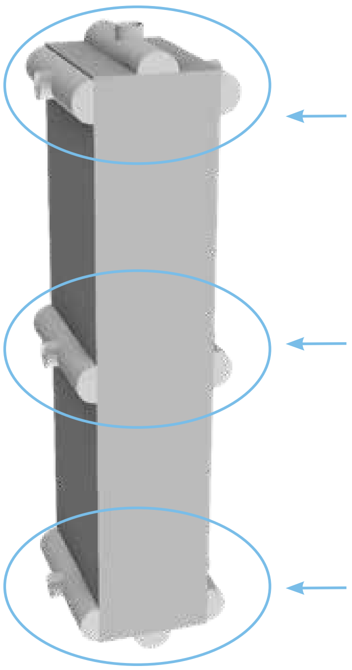
Limit pressure and external loads in the BAHX to those specified by Chart.

Chart offers the following guidelines to minimize thermal fatigue.

1. Limit the temperature difference between the streams at any point along the exchanger length to 50 °F (28 °C) (See Figure XVII).
2. If a stream temperature difference at introduction exceeds 50 °F (28 °C), introduce the flow slowly (crack the valve) until the stream temperature difference is within 50 °F (28 °C) and then slowly ramp the flow rate to full flow.
3. For frequent events (what could be labeled steady state flow) limit the cyclic stream temperature fluctuations to 1.8 °F (1 °C).
4. For infrequent events like startup and shutdown, limit the stream inlet and outlet temperature rates of change to less than 108 °F/hr (60 °C/hr) with allowance up to 3.8 °F/min (2 °C/min).

FIGURE XVII

Temperature Difference Recommendations



III. C. STARTUP, OPERATION, AND SHUT DOWN

Note that all temperature rates of change should be calculated using the time interval specified in the rate of change time unit, i.e. use one minute intervals when calculating temperature rates of change against rates of change per minute and use one hour intervals when comparing against rates of change per hour. Do not use instantaneous rates of change calculations. For example if a stream temperature changed by 0.5°C in 3 seconds (an instantaneous rate of change of 10°C/min) but then only changed by a total of 1°C over a one-minute interval, the temperature rate of change is 1°C/min.

If the flow in one stream stops suddenly, often the recommended course of action is to immediately stop the flow of all other streams to avoid a rapid warm-up or cool-down. This should be evaluated by the system designer / operator on a case-by-case basis for importance (e.g., stopping a stream with insignificant contribution to the overall heat exchange might not be cause for stopping flow of all other streams).

III. C. 4.

The guidelines above reference stream temperatures since stream temperatures are readily available to plant operations. However, these guidelines were developed for local metal temperature differences and local metal temperature rates of change. Thermal stress arises from local metal temperature differences in BAHX components that are close and rigidly attached in all directions.

However, local metal temperature differences are not readily available nor easily measured. Commercially available software tools calculate adjacent parting sheet wall temperatures; one can substitute adjacent parting sheet temperatures for stream temperatures in the guideline. In most cases, a properly designed heat exchanger will have much lower adjacent parting sheet wall temperature differences than stream temperature differences.

Fatigue is defined as repeated stresses resulting in fracture. A standard tool in fatigue is the S-N curve, stress versus the number of cycles. Fatigue is influenced by both the magnitude of the stress and the number of occurrences of the stress. An assumption in the guideline is when the guidelines are followed, one would expect to achieve uninterrupted heat exchanger operation without a fracture (leak) for the expected life of the heat exchanger. It is also why the temperature rate of change of 2 °C / minute is allowed for infrequent events like startup and shutdown since the assumption is the number of events is not frequent. But for steady state operation where the number of events is greater, the rate of temperature change is reduced to 1 °C /minute.

For many situations, exceeding the guidelines will not produce fractures. However, as the magnitude of exceeding the guidelines increases and as the number of occurrences increase, the probability to produce fractures increase. Highly specialized software tools are required to assess the impact of thermal events and the calculated number of occurrences before fracture occurs. The calculated number of occurrences have a range since no two identically manufactured heat exchangers would fracture at the exact same magnitude of loads and occurrences. The calculations are limited to a few selected examples of excursions. This means that predicting exactly when a BAHX will fail or the exact lifetime left in the unit is not possible. The calculated number of cycles to fatigue should be viewed as an estimate with a range.

III. C. STARTUP, OPERATION, AND SHUT DOWN

III. C. 5.

The high thermal conductivity of aluminum helps to minimize temperature differences in BAHX, but large local metal temperature differences can arise from operational instabilities, changes in operating conditions, or transient events associated with startup, shutdown, or upset conditions. Operational instabilities can result from unstable boiling within the BAHX or from externally produced hydraulic fluctuations caused by improperly designed piping systems or inadequate control systems. Detrimental transient events associated with startup, shutdown, or upset conditions can result from improper procedures or inadequate control systems.

To prevent damage from these conditions the following is recommended:

- Review plant operations to identify operating conditions that have the potential to create high thermal stress and develop procedures to minimize the impact of these events. Typical conditions causing high thermal stress include cold and warm restarts. A cold restart is defined as restarting flow while the BAHX is cold from prior operations. A warm restart is restarting flow after the BAHX has been warmed to near ambient conditions.

- Flow control is particularly critical when introducing liquid or two-phase streams. Liquid and two-phase fluids have a large capacity to rapidly change metal temperature in the BAHX. Flow control is less critical when introducing and sensibly heating or cooling vapors due to the limited capacity of the vapor to rapidly change metal temperature in the BAHX. For this reason, cooling or warming of the BAHX to or from operating conditions with a vapor prior to introducing a liquid or two-phase stream is highly recommended.

- Continuously monitor the BAHX in applications where the fluid must be totally vaporized in the BAHX and there is potential for unstable boiling. Adjust the process conditions (flow, temperature, pressure) when necessary to avoid this condition (e.g., increasing flow often helps to stabilize this condition).The relatively large temperature differences associated with unstable boiling along with surging of the vaporizing fluid within the BAHX can cause thermally induced fatigue failure.

- Design and operate the plant equipment and piping connected to the BAHX to prevent flow instabilities (for example, intermittent slugging of liquid to the BAHX). This is extremely important with boiling streams.

- Maintain cleanliness of all streams feeding the BAHX at all times during operation, and properly protect the BAHX from contamination when not in use. Contamination from solid debris, foulants, and material freezing out of the streams internal to the BAHX may lead to stream maldistribution within the BAHX. Internal metal temperature differences can increase with maldistribution and may have the same detrimental effect as stream temperature differences. The internal metal temperature differences are often impossible to observe, so preventing contamination and maldistribution in the BAHX is critical to eliminate this possibility.

III. C. STARTUP, OPERATION, AND SHUT DOWN, III. D. OPERATING RECORDS

- While the guidelines can be useful to determine plant control alarm settings, the guidelines are not recommended plant alarm settings. The process licensor should be consulted on alarm settings. While exceeding the guidelines is not recommended it is not beneficial to install nuisance alarms that may be turned off by operations. Some operations benefit from temperature rate of change indicators rather than alarms.

In instances where it is not possible to adhere to these guidelines, contact Chart to discuss your specific application.

III. C. 6.

Core-in-Kettle® BAHX may use the following simplified startup procedure. Slowly fill the shell with refrigerant until the liquid level is at the normal level shown on the general assembly drawing. Once filled, allow the system temperatures to equilibrate for at least 0.5 hour. Before proceeding, activate the automatic control system to allow it to maintain the nominal liquid level. Slowly introduce the warm stream into the heat exchanger. Gradually increase the warm stream flow rate to full flow while adhering to the guidelines in Section III. C. 3.

III. C.7.

Operating flow rates should be within the Chart specification limits for design or over design flow conditions. If higher flow rates are being considered, contact Chart for recommendations regarding maximum velocities inside the BAHX.

III. C. 8.

Precautions should be taken to prevent the transmission of operating fluid pulsations or vibrations (emanating from pumps, compressors, etc.) to the BAHX.

III. C. 9.

During prolonged or indefinite shut downs (mothballing), see Section IV. D. for recommendations.

III. C. 10.

For air separation reversing BAHX, limit the number and duration of upsets and cold or emergency shut downs in order to prevent repeated freezing of moisture which may have accidentally accumulated in the BAHX.

III. C. 11.

Recommendations for blowdown:

- Shut off flow from the top of the exchanger and vent through the bottom of the exchanger. This will establish parallel (cocurrent) flow and minimize heat transfer during blowdown

- Minimize the distance between the blowdown valves and the BAHX to minimize the stream volume transferred through the BAHX during blowdown.

III. D. Operating Records

Operating outside the guidelines stated in Section III. C. may lead to excessive thermal stress which could result in failure of BAHX components or lead to rupture even when operating within the design limits on the nameplate. An operating log should be kept to record normal operation procedures, any plant upsets, shut downs, and any other operating conditions. It is critical the operating data be monitored to ensure operation is within the IOM stated guidelines.

Given their criticality in determining cause, resolution and responsibility for any issues with the BAHX, the owner should maintain adequate installation, operation, and maintenance records to ensure compliance with the guidelines (see Section II. H. and III. C.).

IV. MAINTENANCE

A. Warning Signs

B. Field Leak Testing

C. Cleaning

D. Mothballing

E. Repair and Service

F. Disposal

IV. A. WARNING SIGNS

IV. A. Warning Signs

Potential warning signs where equipment requires inspection or repair prior to continued operation:

- Operating data indicates equipment is being subjected to operating conditions exceeding guidelines in Section III. C.
- Measurement of stream compositions indicating cross contamination has developed
- Other BAHX at the facility have developed leaks or failures
- Frost spots on cold box wall or insulation sheeting
- Liquid drainage from BAHX or from under insulation
- Indications from gas detection sensors
- Venting from the BAHX
- Smart Layer® Alarm

If any of these warning signs are present contact Chart.

PRIOR TO THE INSPECTION, TESTING, OR REPAIRING OF ANY UNIT, EITHER IN SERVICE OR RECENTLY REMOVED FROM OPERATION, THE SYSTEM MUST BE SAFETY CHECKED AND CLEARED PRIOR TO THE ADMITTANCE OF PERSONNEL FOR ANY SERVICE FUNCTION.

IV. B. FIELD LEAK TESTING

CAUTION MUST BE EXERCISED WITH REGARD TO THE FLAMMABILITY, TOXICITY, EXPLOSION POTENTIAL, OR PRESSURE POTENTIAL OF ANY FLUID OR STREAM WITHIN OR IN THE PROXIMITY OF THE BAHX. ALL PERSONNEL INVOLVED WITH INSTALLATION OR MAINTENANCE OF COLD BOX ASSEMBLIES MUST BE MADE AWARE OF THE DANGERS OF SUFFOCATION, ESPECIALLY IN NITROGEN FILLED CONTAINERS.

FAILURE TO OBSERVE PROPER SAFETY PRECAUTIONS IN THIS REGARD COULD RESULT IN EQUIPMENT RUPTURE, FIRES, TOXIC GAS OR FLUID ESCAPE, SUFFOCATING GAS ATMOSPHERES OR OTHER ACCIDENTS WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

IV. B. Field Leak Testing

Internal leaks in a BAHX are generally indicated by a change of purity in any of the fluid streams. External leaks can be determined by sight, smell, audible sounds of leaking fluid, external gas monitoring equipment, or localized cold spots appearing on the external insulation or cold box casing. External leaks in BAHX mounted in a cold box are also generally indicated by excessive venting through the breather valve or cold spots on the cold box casing. Breather valve gas detection methods are within the scope of operator.

DO NOT EXCEED THE MAXIMUM WORKING PRESSURE SPECIFIED FOR EACH STREAM ON THE CHART NAMEPLATE. OVER–PRESSURIZATION COULD RESULT IN A RUPTURE OF THE BAHX WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

IV. B. FIELD LEAK TESTING

It is critical that any leaking BAHX be repaired immediately and that the cause of the leak be identified and corrected. Prolonged operation may lead to further damage of the unit when the cause is due to cyclical thermal or mechanical fatigue. Prolonged operation of an externally leaking BAHX installed in a perlite insulated cold box may lead to further damage and increased leakage due to perlite erosion of the BAHX metal.

Common field tests used for determining leaks are described below.

IV. B. 1. Pressure Decay Test

Pressurize a stream with dry air or nitrogen.

A stream is considered leak free if it maintains the original pressure for over eight hours with correction for temperature changes. Keep in mind that the pressure decay time test is a function not only of the leak size but the test pressure, temperature, and BAHX size, as well.

For large BAHX and assemblies with large internal volumes, and/or for leak tests at lower pressures (less than 50 psig [3.4 barg]), leaks may take longer than eight hours to detect, depending upon the size of the leak.

The BAHX temperature should be the same at the two pressure checks since any change in temperature will change the air pressure in the BAHX. If it is impractical to make the two pressure checks when the temperatures are the same, the following pressure correction can be used:

$$P_2 = \frac{P_1 T_2}{T_1}$$

Where

P = Absolute Pressure

T = Absolute Temperature (°R or K)

1 = Initial Reading

2 = Final Reading

For individual recommendations, contact Chart.

IV. B. 2. Air-Soap Test (External Leaks)

If the stream does not maintain the original pressure during the decay test, above, determine what kind of leak exists by repressurizing the stream and checking the exterior of the BAHX with a soap bubble test. If the BAHX passes this test, the leak is internal.

DO NOT EXCEED THE MAXIMUM WORKING PRESSURE SPECIFIED FOR EACH STREAM ON THE CHART NAMEPLATE. OVER–PRESSURIZATION COULD RESULT IN A RUPTURE OF THE BAHX WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

IV. B. FIELD LEAK TESTING

IV. B. 3. Internal Leak Testing

The method used to locate the individual layer leak involves a soap test over each port of the stream in question while air or nitrogen pressure is applied to the other stream. This operation normally involves removal of the header and should only be performed by Chart authorized service personnel.

IV. C. CLEANING

IV. C. Cleaning

If the BAHX is fouled or plugged, several options are available to the user for cleaning the BAHX. When the fouling is solid and coats the fins in the BAHX, the BAHX should be cleaned by chemical removal through a series of deriming, back flushing, and drying procedures (see Section IV. C. 1.).

If the BAHX is fouled or plugged by hydrates and/or ice, a warm derime is required and consideration given to other methods for hydrate suppression (see Section III. B. 2.).

If the BAHX is fouled or plugged by particulate matter, back puffing procedures are usually successful in cleaning the BAHX (see Section IV. C. 2.).

The piping and instrumentation diagrams should be carefully reviewed at the plant design phase to ensure adequate nozzles and valves on the piping are available to carry out any of the above cleaning procedures that are anticipated.

IV. C. 1. Deriming, Back Flushing, and Drying

Deriming and back flushing involves the use of heat and/or solvents to remove hydrates, heavy hydrocarbons, waxy materials, compressor oils, or other soluble matter which freeze or collect in the BAHX. The presence of these materials is detected by an increase in the stream pressure drop and/or loss of heat transfer performance. As a general guideline, if the measured pressure drop begins to exceed 2 to 3 times the design pressure drop, Chart would recommend cleaning efforts be undertaken.

When systems for injecting methanol during operation have not been provided (see Section III. B. 2.), shut down and purge the BAHX and allow it to warm and defrost itself by natural heat leak or by an approved derime procedure. Normally, the combination of warming and back flushing with a solvent rinse such as trichloroethane, toluene, propanol, or methanol is successful for this purpose.

Prior to startup, purge and dryout the BAHX in accordance with III. C. 1.

If a water based solvent is used to derime or back flush, or if water accidentally gets introduced into the BAHX, the BAHX must be completely dried before returning to service in order to prevent plugging or rupture caused by freezing. Use dry air or nitrogen or other dry gas as the drying medium.

IV. C. 1. a.

The derime, back flushing, or drying temperature should not exceed 150 °F (65 °C), unless the maximum working temperature on the Chart nameplate is higher. Do not exceed the maximum working temperature specified on the Chart nameplate.

IV. C. 1. b.

The derime, back flushing or drying media must be non-corrosive to aluminum. Always use clean fluids. If any vessels, piping, or temporary pipe sections are used during the cleaning, it is important to clean them of pipe scale, dirt, weld slag, or any other foreign material which could enter and plug the BAHX.

IV. C. CLEANING

IV. C. 1. c.

When liquid solvents are used for purposes of deriming or back flushing the BAHX, the nozzle fluid velocity should not exceed 10 feet (3 meters) per second to prevent erosion inside the BAHX. Liquid solvents or any cleaning fluids should always be circulated through the BAHX in the reverse direction of normal operating flow.

IV. C. 1. d.

Cleaning solvents should always be chosen with regard to the suspected fouling agent. If the fouling agent is unknown, a sample of it should be chemically analyzed to determine its composition.

ONLY CLEANING SOLVENTS THAT ARE NON-CORROSIVE TO ALUMINUM MUST BE USED. CORROSIVE CLEANING SOLVENTS CAN WEAKEN PRESSURE RETAINING STRUCTURES WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

If any special procedures are required to meet uncommon derime, back flushing, or drying conditions, contact Chart for further evaluation.

IV. C. 2. Back Puffing

When proper precautions are taken regarding filtering, many years of clean service can be expected. However, when foreign material (pipe scale, perlite, desiccant, mole sieve, etc.) is introduced into the BAHX itself, by accident or misoperation, back puffing can be an effective method for removing entrained particulates.

Since particulates normally cause blockages in the BAHX at the inlet ports and distributors, puffing in the reverse direction of normal operating flow is required to prevent pushing the particulates farther into the BAHX. The back puffing procedure involves attaching a rupture disk to the inlet nozzle or flange of the BAHX stream to be backpuffed.

INTRODUCTION OF WATER/AQUAEOUS CLEANING SOLUTIONS TO ANY BAHX EXPOSED TO MERCURY CONTAMINATION CAN RESULT IN ACCELERATED CORROSION AND CAN CAUSE IRREPARABLE DAMAGE AND POTENTIAL CATASTROPIC FAILURE AND EXPOSE PERSONNEL TO HAZARDOUS AND UNSAFE WORKING CONDITIONS.

IV. C. CLEANING

IT IS THE USER'S RESPONSIBILITY TO TAKE THE APPROPRIATE SAFETY PRECAUTIONS REGARDING PERSONNEL, CLEARING THE TEST AREA, AND THE SUITABILITY OF THE SUPPORTS AND BRACING TO WITHSTAND THE REACTION FORCES DEVELOPED WHEN THE RUPTURE DISK BURSTS.

EXTREME CAUTION MUST BE EXERCISED AS THE RUPTURE OF THE DISK AND THE RELEASE OF GAS CAN RESULT IN A RAPID DISCHARGE OF GAS AND FLYING DEBRIS WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

The plugged stream is slowly filled with dry air or nitrogen until the rupture disk bursts. The sudden release of gas out of the BAHX will help dislodge particulate matter. This back puffing procedure should be repeated five to ten times, or until the amount of particulate removed becomes minimal and the discharge cloud is clear.

EXTREME CAUTION MUST BE EXERCISED SO AS NOT TO EXCEED THE MAXIMUM WORKING PRESSURE OF THE STREAM ON THE CHART NAMEPLATE, OR 100 PSIG, WHICHEVER IS LESS.

FAILURE TO LIMIT PRESSURIZATION TO THESE LIMITS COULD RESULT IN A RUPTURE OF THE BAHX WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

Contact Chart for guidance on the maximum allowed backpuffing pressure. If the maximum allowable pressure is reached and the rupture disk has not burst, the stream should be depressurized and a new rupture disk installed.

A back puffing event does not reduce the life of the equipment. However, remaining residue in the equipment has the potential to distort the thermal profile and induce thermal stress, which may reduce the life of the equipment.

IV. D. MOTHBALLING

IV. D. Mothballing

BAHX which have seen prior service should be dried and pressurized prior to storage. An eight hour or longer purge with dry air or nitrogen having a dew point less than 32 °F (0 °C) is recommended to dry the BAHX.

Following the drying operation, each stream should be pressurized with dry air or nitrogen with a dew point of less than -40 °F (-40 °C). This low dew point is recommended to prevent galvanic corrosion in the BAHX which could result if traces of rust or other foreign materials have gained access to the BAHX during operation. The dry air or nitrogen pressure should be 15 psig (1 barg) or one third the stream design pressure, whichever is less.

The 15 psig (1 barg) pressure level should be checked periodically to assure that there are no leaks in the BAHX. In addition, the storage recommendations in Section II. B. should also be followed.

IV. E. REPAIR AND SERVICE, IV. F. DISPOSAL

IV. E. Repair and Service

If a leak is detected, Chart should be notified for repair recommendations. Chart is well qualified and staffed to perform field or factory service and repair on this type of BAHX equipment.

Refer to the National Board Number and the Chart serial number shown on the ASME U-1 data report form or unit nameplate when contacting Chart.

All ASME repairs must be certified by an “R” stamp and must be in accordance with the Chart Quality Assurance Policy, the National Board Inspection Code, and the ASME Code, and any local jurisdictional requirements.

Repair to the BAHX should be made only by Chart authorized personnel. The Chart warranty will be voided if repairs made to the Chart BAHX during the warranty period are made by unauthorized service personnel.

Improper welding on the BAHX block can damage the braze joints. Repairs not made in accordance with ASME procedure, and identified by the “R” stamp on the Chart nameplate, will invalidate the National Board registration of the BAHX.

In the GPA Midstream Technical Bulletin – Brazed Aluminum Heat Exchangers, GPA-TB-001 December 2020 it says:

“Consider replacing a heat exchanger within a reasonable amount of time if analysis of historical operating data shows that thermal fatigue contributed to the leak and especially if the heat exchanger requires a second leak repair due to thermal fatigue.”

Chart endorses the GPA recommendation.

IMPROPERLY REPAIRED BAHX MAY NOT BE SUITABLE TO WITHSTAND THE NAMEPLATE MAXIMUM WORKING PRESSURE RATINGS.

PRESSURIZATION OF AN IMPROPERLY REPAIRED BAHX COULD RESULT IN A RUPTURE OF THE BAHX WHICH MAY RESULT IN SERIOUS BODILY INJURY OR DEATH AND PROPERTY DAMAGE AS WELL AS IRREPARABLE DAMAGE TO THE CHART EQUIPMENT AND THE VOIDING OF ANY WARRANTIES APPLICABLE TO THE EQUIPMENT.

IV. F. Disposal

When disposing of a BAHX, Chart encourages recycling whenever possible. A drained heat exchanger may have residual compounds inside from prior use. Due to accumulation over time, the residual compounds may be present in more concentrated amounts than experienced in the product stream. Owners should be aware that their BAHX may have residual compounds of sufficient quantity to pose a safety or environmental hazard. Owners should know the composition of the residual compounds and consider the safety and environmental impacts of those compounds before sending their BAHX to a metal recycler. Disposal must be in accordance with all applicable laws and regulations.

Chart Energy & Chemicals, Inc. is an ISO:9001, ISO:14001, and OHSAS:18001 registered company

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INSTALLATION, OPERATION, AND MAINTENANCE MANUAL

for Chart Brazed Aluminum Heat Exchangers (BAHX) and Core-in-Kettle® Assemblies.

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