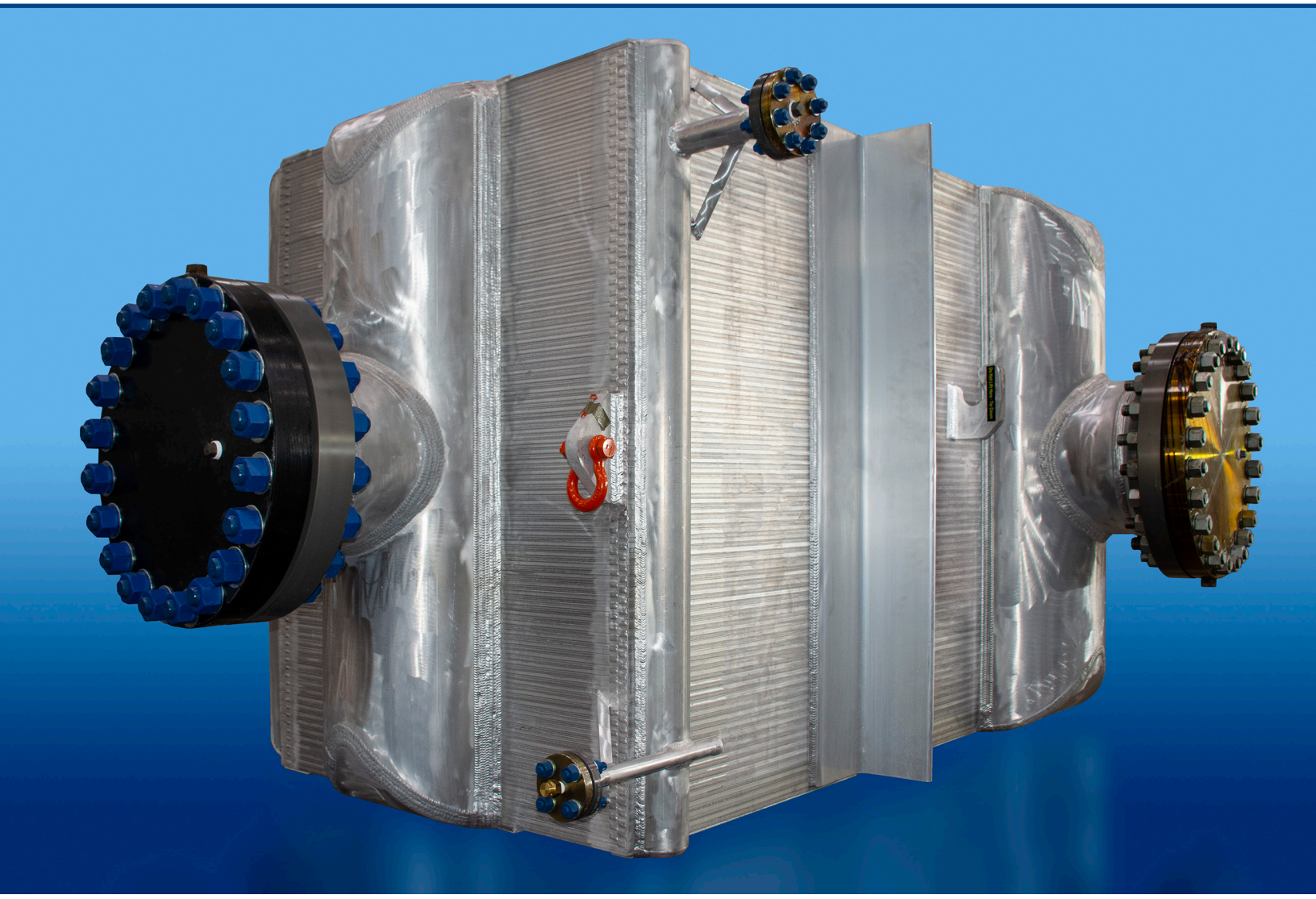


Smart Layer®

CHART®

Cooler By Design®

Rev. 1

Principles of Operation

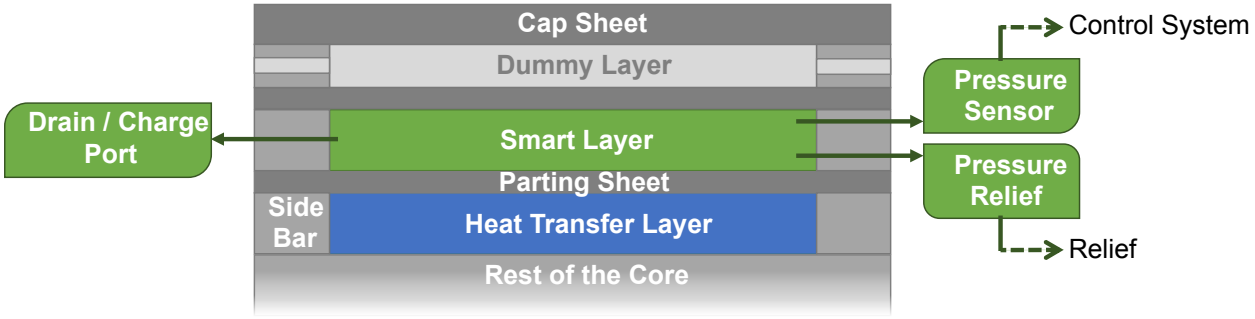
Smart Layer is a Chart patented feature that provides an early indication of fatigue damage occurring in a brazed aluminum heat exchanger (BAHX) prior to any loss of process fluid containment. It operates on the fact that thermal fatigue typically accumulates fastest in the outside cap and parting sheets. For BAHX equipped with Smart Layer, an outside dummy layer is converted into a pressurized inactive layer charged with low-pressure nitrogen. By monitoring the Smart Layer pressure while the BAHX is in operation, an operator can determine if any fatigue cracks have formed in the outer parting sheets.

Key Features:

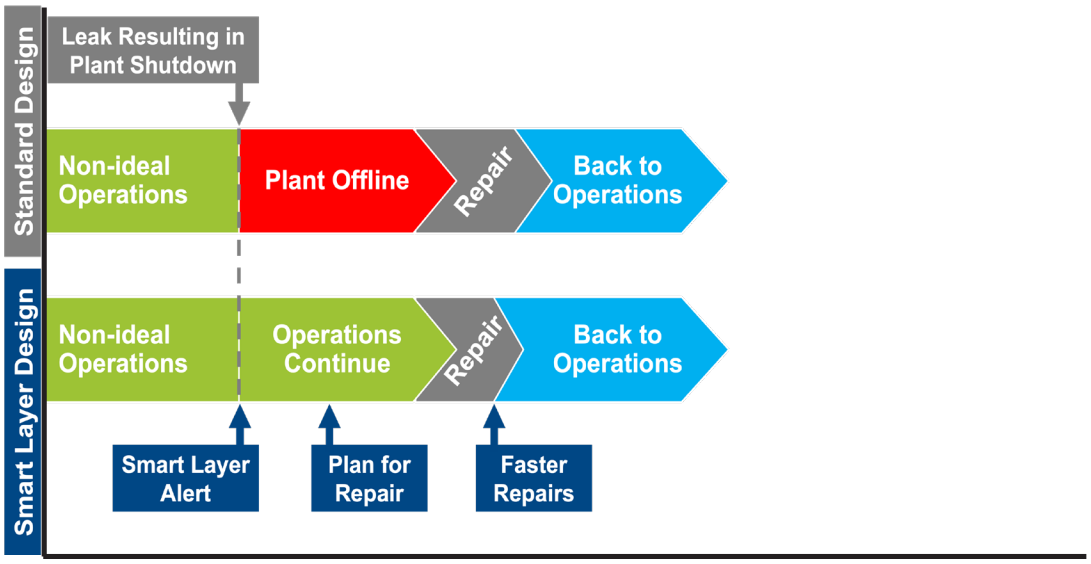
- Rated to max MAWP of BAHX
- Proven through successful field operation
- Repairable

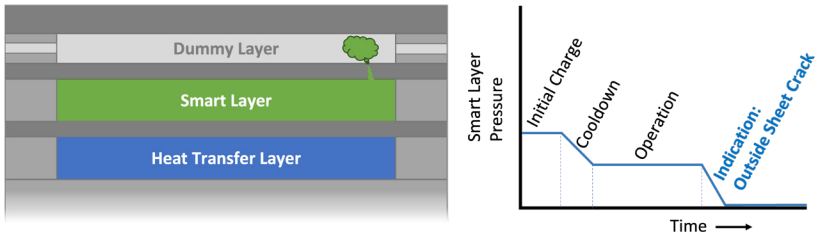
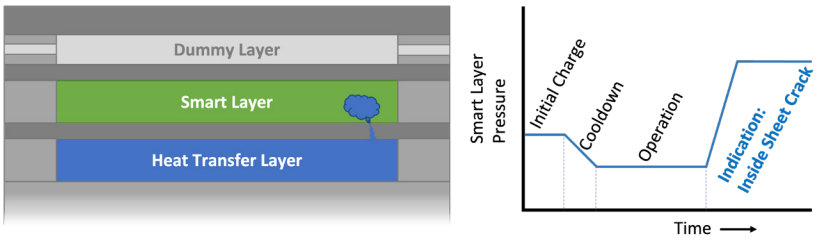
Value Added:

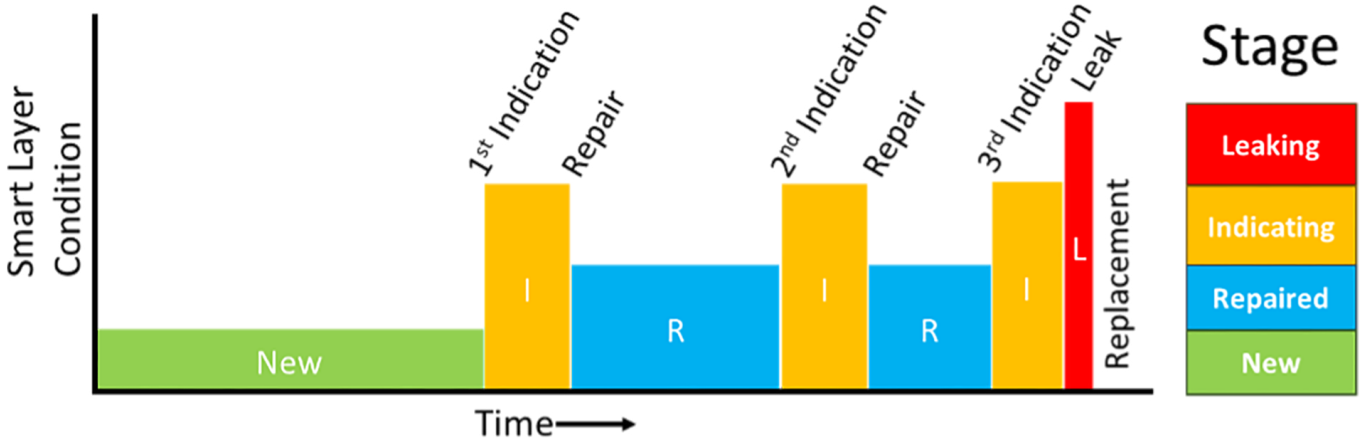
- Early indication of fatigue damage prior to any loss of containment
- Passive protection – peace of mind
- Field proven to reduce risk and increase uptime
- Low cost insurance to protect against unplanned shutdowns



In practice, a user may install a BAHX equipped with Smart Layer and, if they operate within the guidelines, will never see an indication of fatigue damage. In other instances, such as in severe service applications, the BAHX may operate normally for years before a fatigue indication occurs. When it does, the user is able to continue operating, but should plan to repair the unit within 3 months.

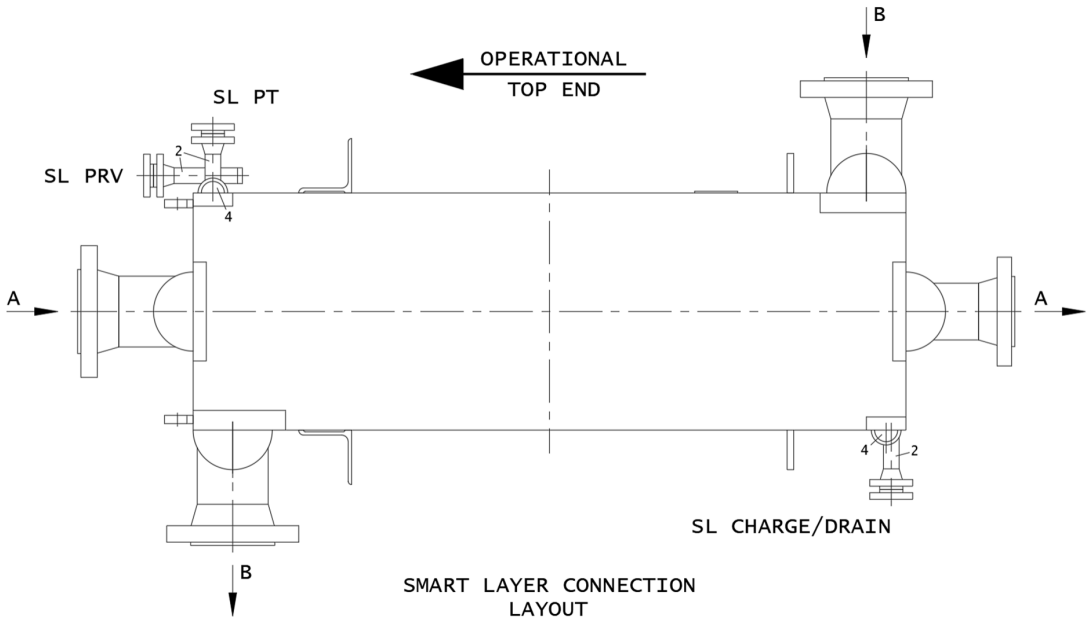


Outside sheet crack Drop in Smart Layer pressure Inert charge vents No process fluid leaking	
Inside sheet crack Process fluid enters Smart Layer Rise in Smart Layer pressure Process fluid contained by Smart Layer No process fluid leaking	



Design Example

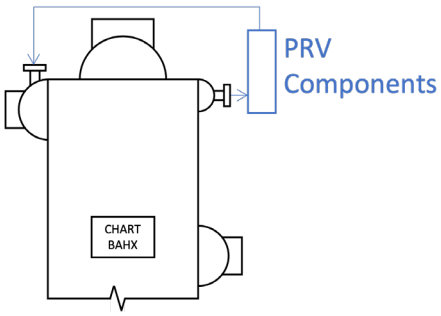
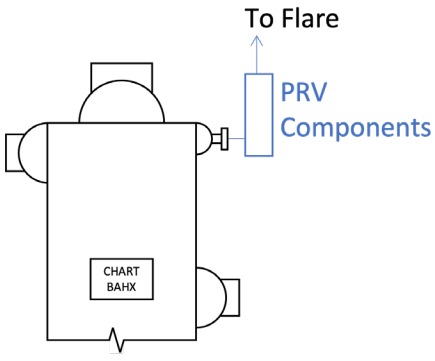
The typical Smart Layer design will include 2 additional headers dedicated to the Smart Layer. The bottom header will have a single nozzle for charging with nitrogen and draining liquids. The top header will have 2 nozzles: one for a pressure transmitter and one for a pressure relief system.



Configuration

Smart Layer allows for multiple configurations of the pressure relief system.

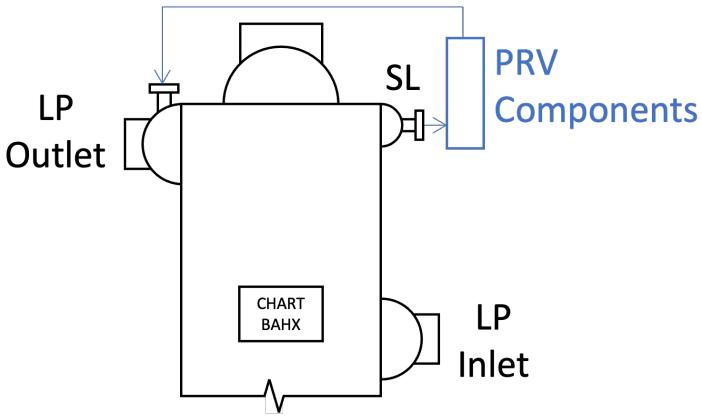
Configuration Comparison

	Self-Contained Relief	External Relief
		
PRV Line Outlet	Low-pressure stream	External piping / flare
Flanged Connections	Optional	Optional
Cold Box Compatible	No	Yes, with welded connections

Self-Contained Relief

The self-contained pressure relief configuration for Smart Layer eliminates the need for an external PRV loop or flare connection by directing the Smart Layer pressure relief to a low-pressure header on the BAHX unit. The customer is responsible for sizing and sourcing pressure relief components. This configuration assumes appropriate pressure relief on the low-pressure stream and sufficient pressure differential between Smart Layer MAWP and low-pressure stream MAWP.

Schematic Examples of Self-Contained PRV System:



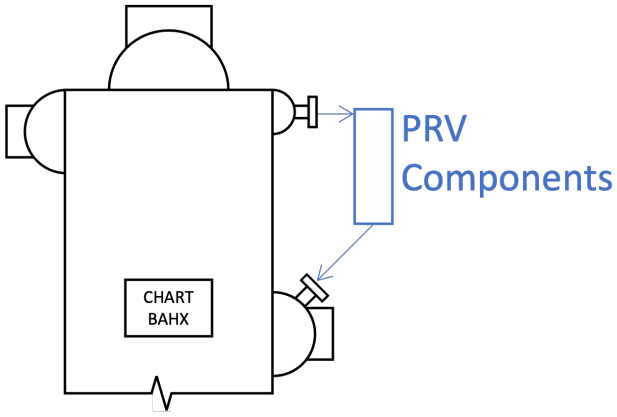
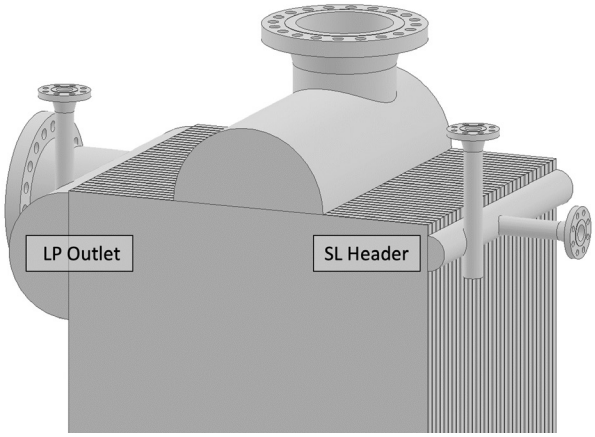
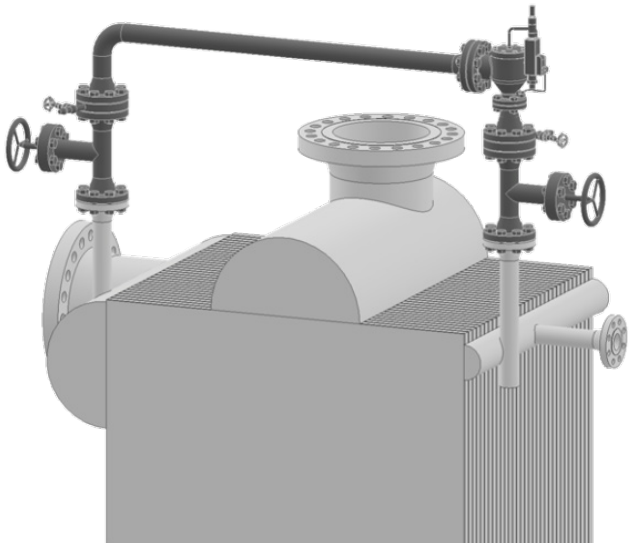


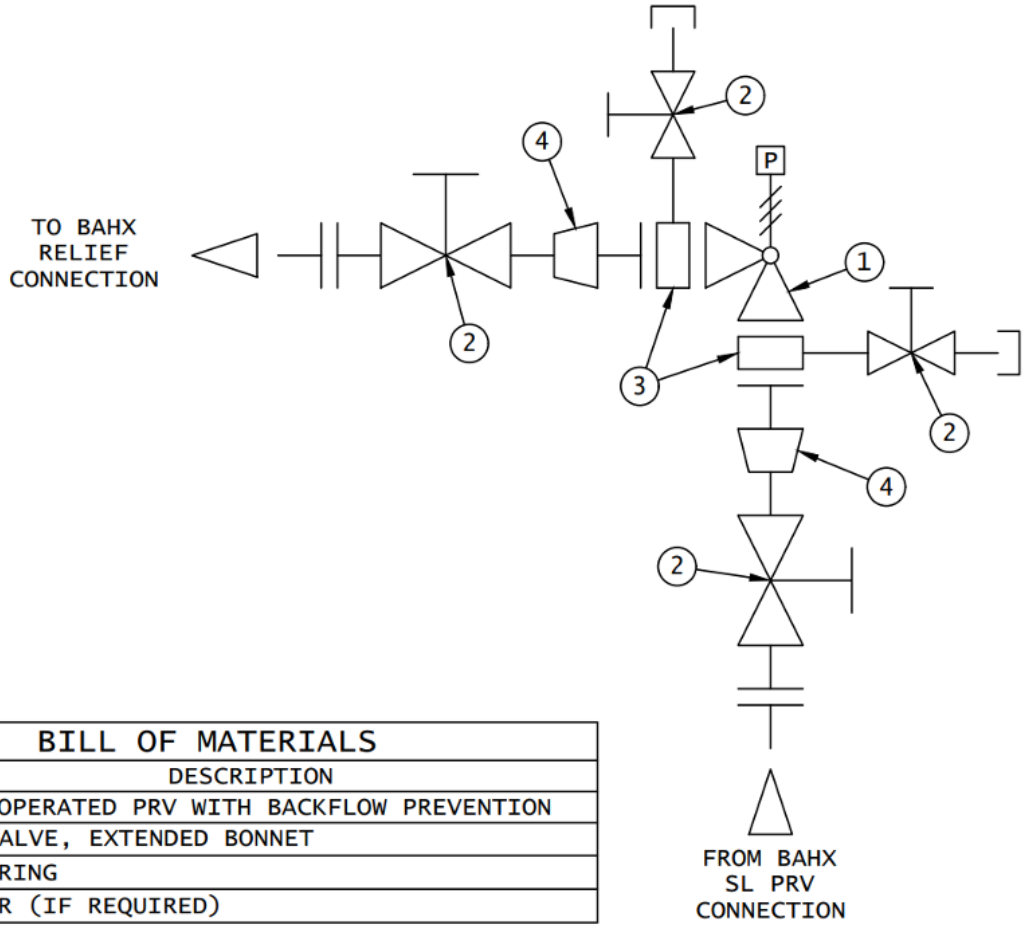
Chart Scope:



3D Example Self-Contained PRV System:



Suggested Self-Contained PRV Loop Components

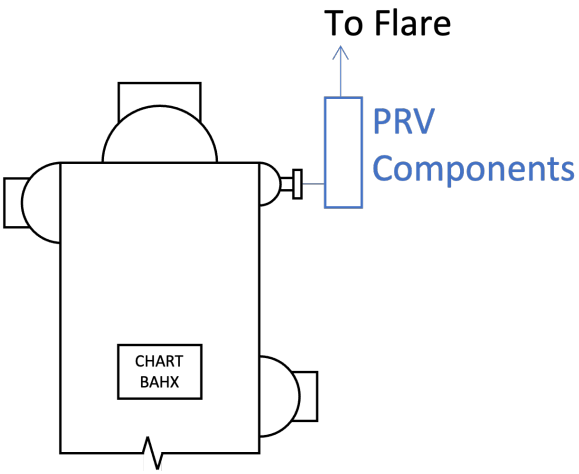


BILL OF MATERIALS	
ITEM	DESCRIPTION
1	PILOT OPERATED PRV WITH BACKFLOW PREVENTION
2	GATE VALVE, EXTENDED BONNET
3	BLEED RING
4	REDUCER (IF REQUIRED)

External Relief

The external relief configuration allows the Smart Layer pressure relief to be directed to an external PRV loop or flare in the customer's scope. The customer is responsible for sizing and sourcing pressure relief components.

Schematic Examples of External PRV System:



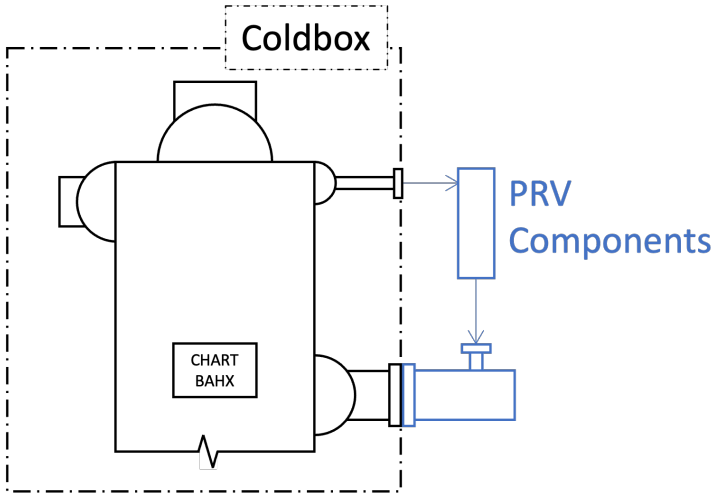
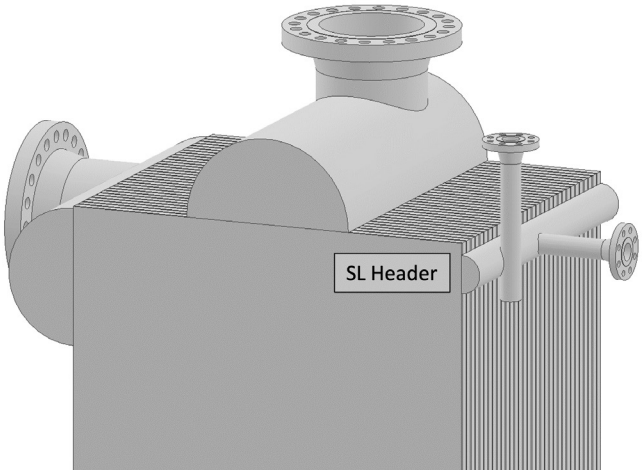


Chart Scope:



PRV Selection

Smart Layer must be provided with dedicated pressure relief. The guidance provided here is based on Chart's experience, which may not be applicable to a specific application. The customer is ultimately responsible for selecting an appropriate pressure relief system for their application.

Typical Hardware

Where the pressure relief is directed into a low-pressure process stream, a 1D2 modulating pilot operated valve with backflow prevention is recommended. Where relief is routed directly to an atmospheric flare, a conventional spring PRV is recommended. Stainless steel body material is recommended when cryogenic temperatures are possible within the exchanger or during relief events.

Sizing Guidance

Chart recommends sizing the PRV using API 521 (7th Ed.) based on the following cases, which are intended to be conservative ("worst-case" requiring maximum relief flow). Each case should be reviewed for suitability to the specific installation by an engineer qualified in sizing pressure relief systems. Perform the sizing calculations for all process streams, but the controlling case is typically the process stream with the lowest molecular weight vapor.

All cases are based on adding heat to a fluid trapped in the Smart Layer, causing pressure to rise. Since the Smart Layer MAWP is equal to or higher than the MAWP of all process streams in the BAHX, there is no scenario where a leak from a process stream into the Smart Layer will require pressure relief under normal operating conditions.

Assumptions common to all cases:

1. A leak has developed between Smart Layer and a process stream, and the Smart Layer has filled with the process stream fluid. Neglect any residual Smart Layer nitrogen charge.
2. All pressure relief must flow through the PRV (no allowance for pressure relief through the original leak).
3. For worst case, assume the Smart Layer temperature is the cold end operating temperature, and the pressure is the MAWP of the process stream. If this is too conservative, use typical operating conditions.
4. Size for maximum rate of vapor formation as described in API 521 section 4.4.13.2.5.2[1]

[1] *For simple vaporizing liquid, the relieving rate is the heat input to Smart Layer divided by the latent heat of vaporization (API suggests assuming 50 BTU/lb if actual values are unavailable)*

Case 1: Pool Fire

BAHX is exposed to an open pool fire. Size using API 521 Section 4.4.13.2

EXPOSED AREA	BOTH CAP SHEET AREAS (BAHX WIDTH * LENGTH * 2)
EXPOSED VOLUME	SMART LAYER VOLUME
MAXIMUM WALL TEMPERATURE T_W	600 °F

Case 2: Loss of Refrigeration

All cold stream flow suddenly stops but all warm stream flow continues, rapidly warming the entire BAHX to the warm end temperature. Size using API 521 Section 4.4.9.1.

WARM SIDE DUTY Q_W	SUM OF ALL WARM STREAM DUTIES
NON-WARM LAYERS L_{NW}	NUMBER OF NON-WARM STREAM LAYERS
HEAT INPUT TO SMART LAYER Q	$Q = \frac{Q_w}{L_{NW}}$

Example Design Specific Instructions

All units equipped with Smart Layer will include instructions specific to that unit.

When the Smart Layer is initially charged after installation or recharged after a repair, consult the Smart Layer Charge Pressure table for the appropriate charge pressure. This table accounts for the change in BAHX temperature so that the target Smart Layer pressure is achieved at operating conditions.

SL Pressure Alarms

High Alarm Setting [psig]	Low Alarm Setting [psig]
80	35

BAHX Operating Conditions

Warm End [F]	Cold End [F]	SL Pressure [psig]
120	-160	50

Uniform BAHX Temperature [F]	SL Charge Pressure [psig]	
100	67.6	
80	64.7	
60	61.8	
40	58.8	
20	55.9	
0	52.9	
-20	50	← Equivalent Operating Condition

Downstream SL Relief Connection

B out header

PRV Sizing Guidance

Pool Fire

Exposed Fire Area [ft^2]	SL Volume [ft^3]
46	4.4

Loss of Refrigeration

Warm Side Duty [Btu/hr]	# Non-Warm Layers [-]
11.7E6	152

Operation

Installation

1. Connect the PRV, pressure transmitter, and charge / drain components.
2. Perform leak test.

Setup

1. Connect pressure transmitter to control system.
2. Configure Smart Layer high / low pressure alarms.
3. Pressurize Smart Layer with nitrogen.
4. Disconnect Smart Layer from nitrogen source.

Monitoring

Daily visual inspection should be carried out to confirm no errant leaks. There is a small chance that a parting sheet and cap sheet crack will occur simultaneouly and the high / low pressure alarms will not activate.

If a high-pressure alarm activates:

1. A crack has occurred between the Smart Layer and a process stream.
2. Smart Layer is now "Indicating".
3. Consider the Smart Layer to be filled with fluid from the adjacent process stream.

If a low-pressure alarm activates:

1. Either a crack has occurred in the cap sheet, or a leak has occurred in the associated Smart Layer piping system.
2. Re-pressurize Smart Layer to confirm leak location. Check the dummy layer vent stubs first.
3. If leak is from vent stubs or BAHX core, the Smart Layer is now "Indicating".
4. If leak is from associated piping system fittings, seal leak and retest.

Indication Response:

1. The BAHX may continue to operate as long as no external process fluid leaks appear.
2. Report indication to Chart.
3. Review operations for root cause of crack. Thermal fatigue damage is a common cause.
4. Make plans to repair the BAHX. No further indications of fatigue damage will occur until repairs are made.
5. In most instances, Smart Layer functionality can be restored after repairs have been made.

Smart Layer®

For more information:

https://www.chartindustries.com/Products/Brazed-Aluminum-Heat-Exchangers

"Introducing Smart Layer" Chart Industries, Sept 2018

"A Smarter System" Hydrocarbon Engineering, Dec 2018

"BAHX Fatigue – Smart Layer Indications versus Simulation Estimations" and

"Smart Layer Saves the Day" GPA Midstream Technical Conference, Apr 2024

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