

Smart Layer™



Principles of Operation

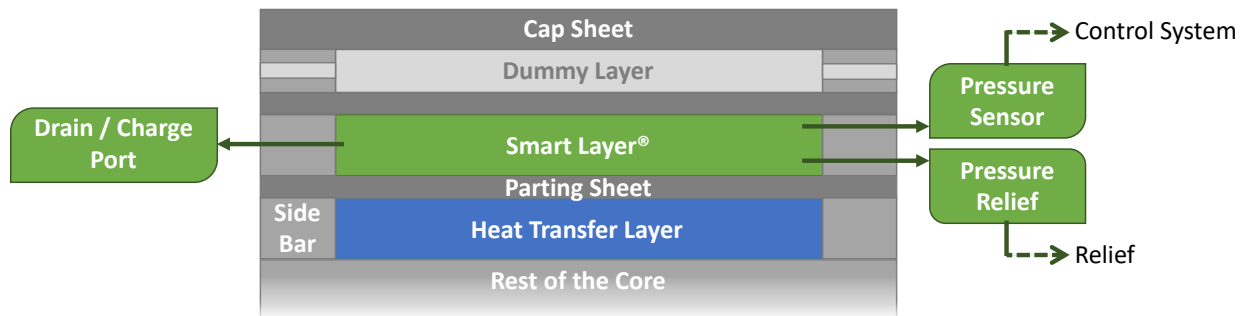
The Smart Layer™ system is a Chart patented feature that provides an early indication of fatigue damage occurring in a brazed aluminum heat exchanger (BAHX) prior to any loss of process fluid containment. It operates on the fact that thermal fatigue typically accumulates fastest in the outside cap and parting sheets. For BAHX equipped with Smart Layer™ technology, 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:

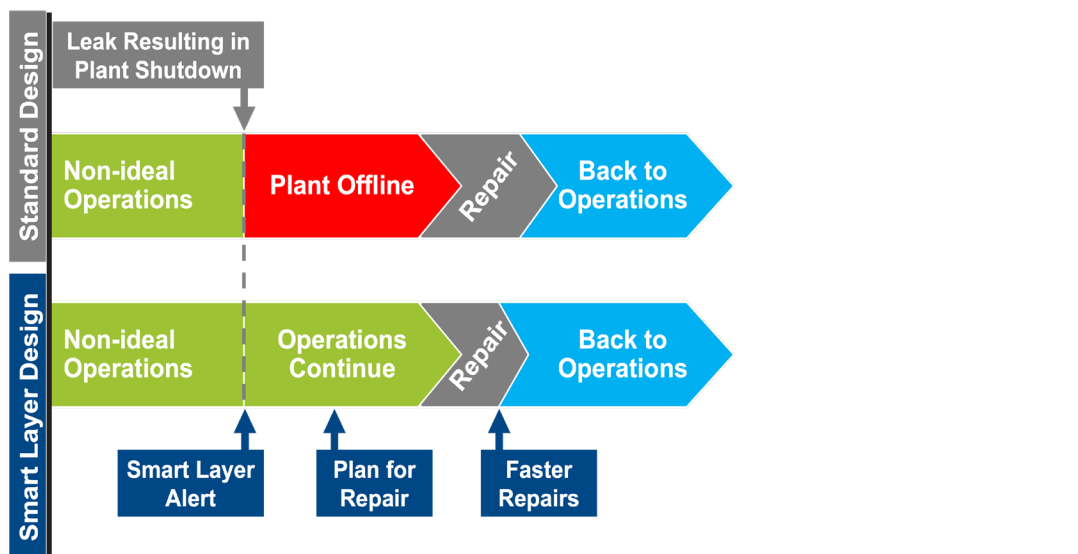
- Rated to MAWP of adjacent stream or higher
- Proven through successful field operation
- Repairable

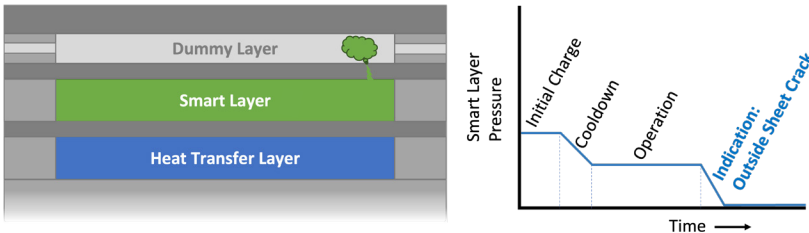
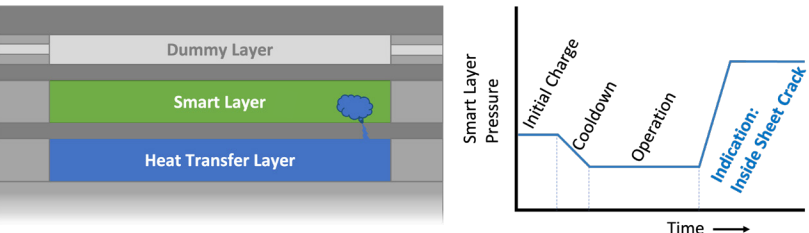
Value Added:

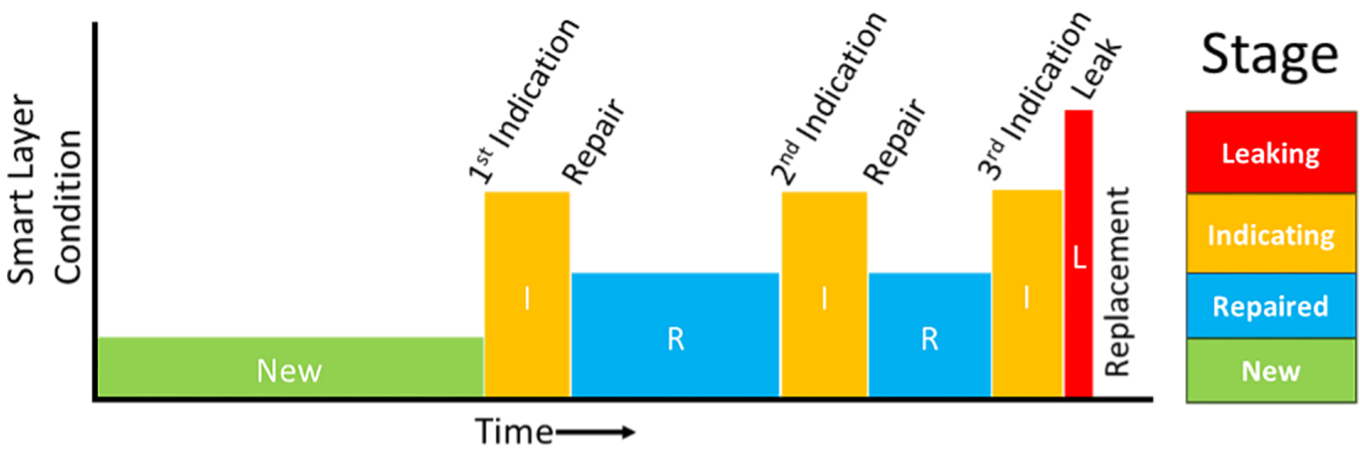
- Early indication of fatigue damage prior to any loss of containment
- Passive protection – peace of mind
- Field proven to reduce risk and increase uptime
- Low cost insurance to protect against unplanned shutdowns



In practice, a user may install a BAHX equipped with Smart Layer™ technology 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.



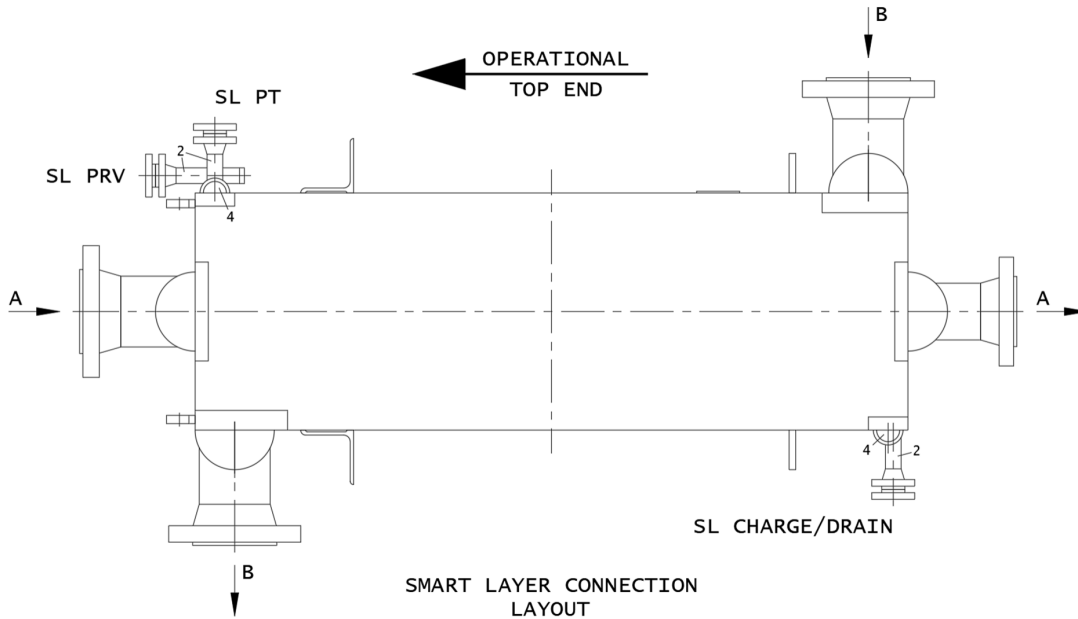
<p>Outside sheet crack</p> <p>Drop in Smart Layer™ pressure</p> <p>Inert charge vents</p> <p>No process fluid leaking</p>	
<p>Inside sheet crack</p> <p>Process fluid enters Smart Layer™ stream</p> <p>Rise in Smart Layer™ pressure</p> <p>Process fluid contained by Smart Layer™ stream</p> <p>No process fluid leaking</p>	



**Chart recommends replacing a BAHX after the second repair.*

Design Example

The typical Smart Layer™ design will include 2 additional headers dedicated to the Smart Layer™ stream. 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

A Smart Layer™ system is provided in different design pressure and pressure relief configurations.

Design Pressure

The Smart Layer™ stream design pressure is determined by Chart and the customer, considering the unique characteristics and reparability of the specific BAHX design.

DESIGN PRESSURE	PRESSURE RELIEF
High Pressure	Self Contained or External
Low Pressure	External

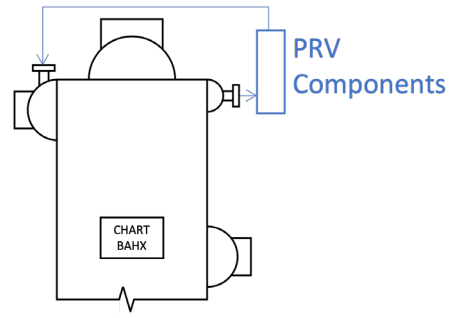
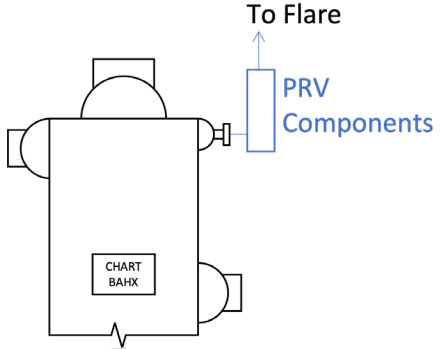
“High-Pressure” (HP-SL)

The Smart Layer™ stream is rated to the MAWP of the highest-pressure stream in the unit. This will be able to contain a leak from any stream, even non-adjacent ones, into the Smart Layer™ stream. It can accommodate self-contained or external pressure relief.

“Low-Pressure” (LP-SL)

The Smart Layer™ stream is rated to the MAWP of the adjacent stream, which is typically the lowest-pressure stream in the unit. This is sufficient for most circumstances, as the most likely Smart Layer™ indication leak will be from the adjacent layer. This also simplifies repairs to restore Smart Layer™ functionality should an indication occur. This is only compatible with external pressure relief.

Pressure Relief Comparison

	Self-Contained Relief	External Relief
		
Smart Layer™ Design Configuration	HP-SL	HP-SL or LP-SL
PRV Line Outlet	Low-pressure process 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 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 the Smart Layer™ stream MAWP and low-pressure stream MAWP. Only compatible with High-Pressure Smart Layer™ designs.

Schematic Examples of Self-Contained PRV System:

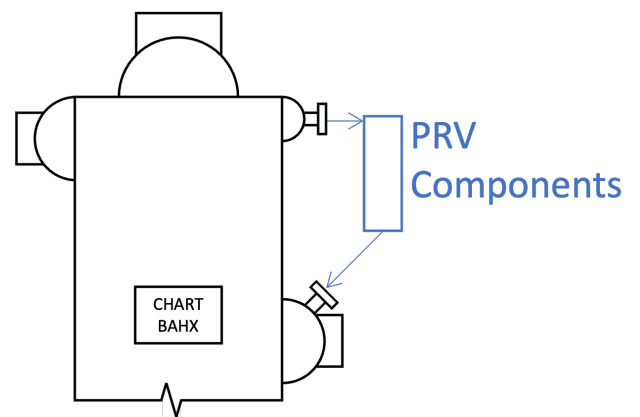
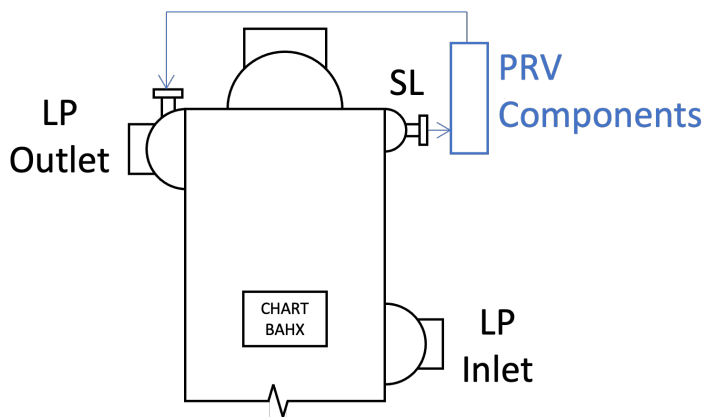
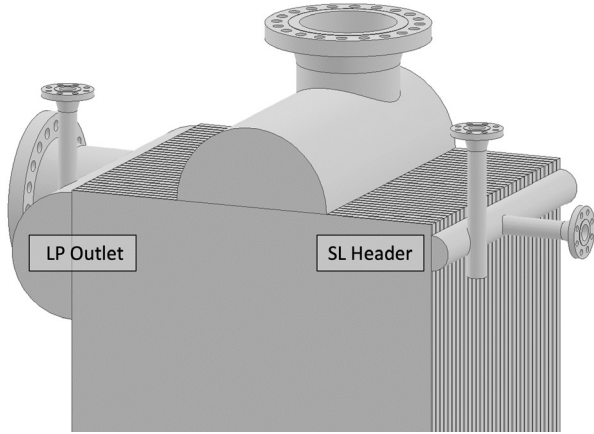
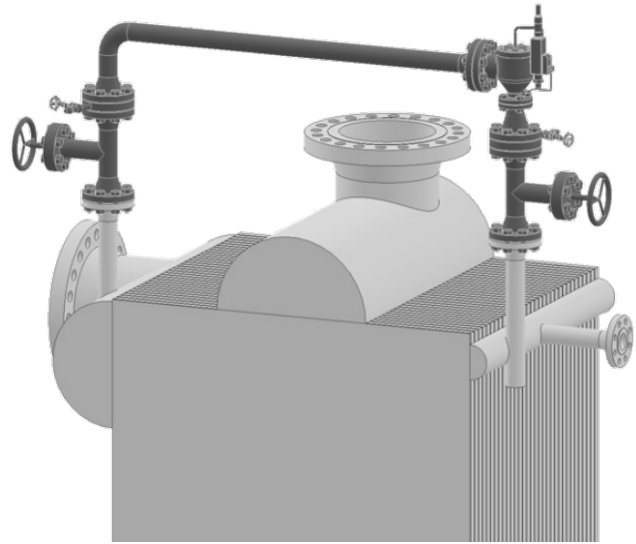


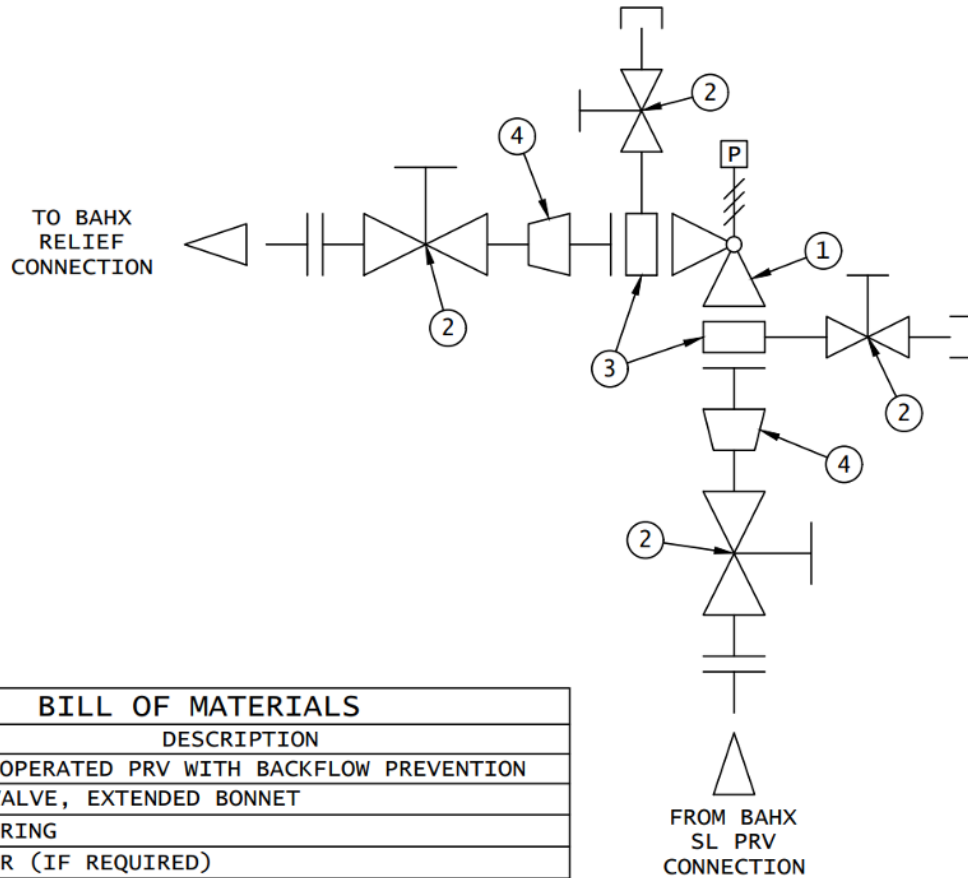
Chart Scope:



3D Example Self-Contained PRV System (Customer Scope):



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. Compatible with High-Pressure and Low-Pressure Smart Layer™ designs.

Schematic Examples of External PRV System:

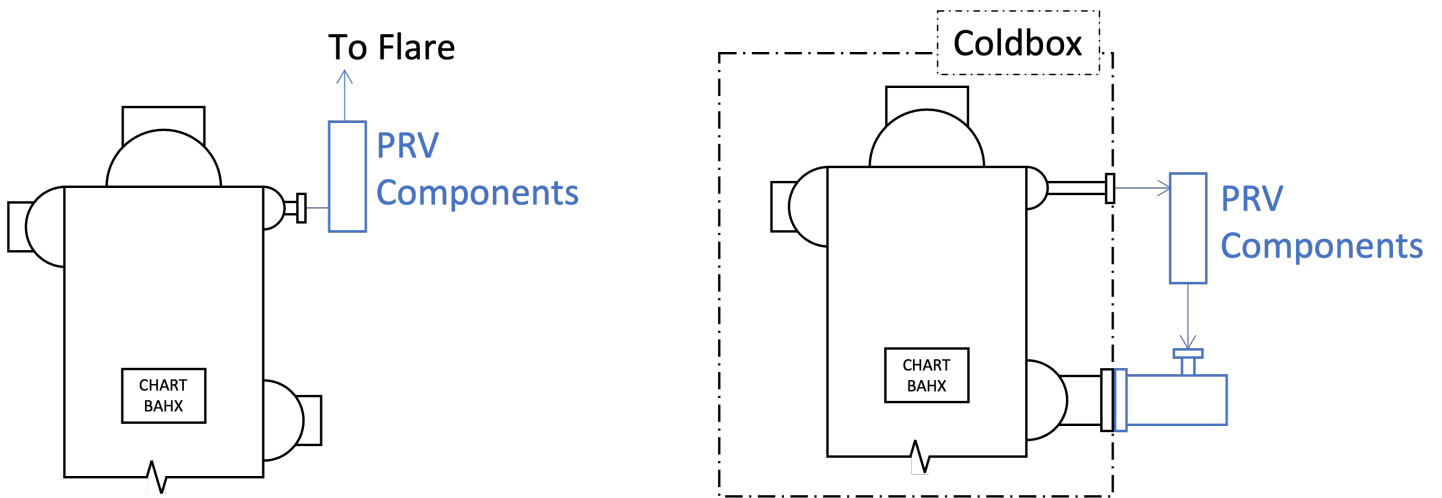
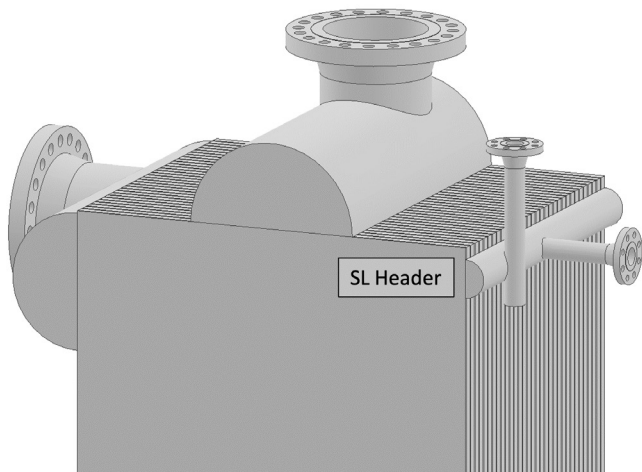


Chart Scope:



PRV Selection

The Smart Layer™ stream must be provided with dedicated pressure relief. The guidance provided here is based on Chart's experience and is intended for general guidance purposes only. It may not be applicable for all applications or processes. The customer is ultimately responsible for selecting and sizing an appropriate pressure relief system for their specific application.

Typical Hardware

Where the pressure relief is directed into a low-pressure process stream, a 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 suggests considering the following cases for sizing the PRV (developed using API 521 7th Ed.) which are intended to be conservative ("worst-case" requiring maximum relief flow). Each case should be reviewed for suitability to the specific instillation by an engineer qualified in sizing pressure relief systems. This engineer should also determine if additional cases not included here should be considered. For each case, perform the sizing calculations for all process streams.

Case 1: Pool Fire and Case 2: Loss of Refrigeration apply to High and Low-Pressure Smart Layer™ designs. Case 3: HP Leak to SL only applies to Low-Pressure Smart Layer™ designs and typically controls.

Assumptions common to all cases:

1. A leak has developed between the Smart Layer™ stream and a process stream, and the Smart Layer™ stream 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. If this is too conservative, use typical operating conditions.

Case 1 and Case 2 sizing (HP and LP Smart Layer™ designs):

4. Assume Smart Layer™ stream is at MAWP of the process stream prior to heating.
5. Size for maximum rate of vapor formation as described in API 521 section 4.4.13.2.5.2¹

Case 3 sizing (LP Smart Layer™ designs):

6. Size for a leak between the highest MAWP stream and the Smart Layer™ stream.

¹ For simple vaporizing liquid, the relieving rate is the heat input to Smart Layer™ stream 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™ STREAM 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.

PROCESS FLUID DUTY Q_{PF}	TOTAL DUTY FOR A GIVEN PROCESS FLUID/STREAM
NUMBER OF PROCESS FLUID LAYERS $\# PF \text{ Layers}$	TOTAL NUMBER OF LAYERS WITH CORRESPONDING PROCESS FLUID/STREAM IN BAHX CORE
NUMBER OF SMART LAYERS $\# SL \text{ Layers}$	TOTAL NUMBER OF SMART LAYERS IN BAHX CORE
HEAT INPUT TO SMART LAYER™ STREAM Q_{SL}	CUMULATIVE HEAT INPUT TO ALL SMART LAYERS $Q_{SL} = \frac{Q_{PF} \cdot \# SL \text{ Layers}}{\# PF \text{ Layers}}$


Case 3: HP leak to SL

CRACK SIZE	0.15 IN ² (1mm X 100mm)
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Example Design Specific Instructions

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

When the Smart Layer™ stream 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. For example, when the core is uninsulated and in an environment where the ambient temperature is 80 °F, an initial Smart Layer™ charge pressure of 60 psig is required to achieve the final target pressure of 50 psig for the Smart Layer™ stream when the BAHX reaches operating temperature.

Chart Energy & Chemicals, Inc.		Document																		
		SL Charge Pressure Guidance																		
PROJECT Example Unit E-01 Spec Sheet 123456X JDE 1234.X		Calc - Date - Checked - Date -																		
DOWNSTREAM SL RELIEF CONNECTION External	SL ALARM SETTINGS SL Operating [psig] 50 High Alarm [psig] 80 Low Alarm [psig] 30																			
BAHX PRIMARY OPERATING CONDITIONS Case Main Operation Warm End [F] 60 Cold End [F] -40	<table border="1"> <thead> <tr> <th>UNIFORM BAHX TEMPERATURE [F]</th> <th>SL CHARGE PRESSURE [psig]</th> </tr> </thead> <tbody> <tr><td>100</td><td>62</td></tr> <tr><td>80</td><td>60</td></tr> <tr><td>60</td><td>57</td></tr> <tr><td>40</td><td>54</td></tr> <tr><td>20</td><td>51</td></tr> <tr><td>0</td><td>49</td></tr> <tr><td>-20</td><td>46</td></tr> <tr><td>10</td><td>50</td></tr> </tbody> </table>	UNIFORM BAHX TEMPERATURE [F]	SL CHARGE PRESSURE [psig]	100	62	80	60	60	57	40	54	20	51	0	49	-20	46	10	50	
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PRV SIZING GUIDANCE Pool Fire <table border="1"> <thead> <tr> <th>Exposed Fire Area [ft²]</th> <th>SL Volume [ft³]</th> </tr> </thead> <tbody> <tr> <td>100.0</td> <td>2.00</td> </tr> </tbody> </table> Loss of Refrigeration Heat Input to Smart Layer™ Stream [BTU/hr] 123456.78	Exposed Fire Area [ft ²]	SL Volume [ft ³]	100.0	2.00	SL filling pressure at different BAHX temperatures to achieve target pressure at BAHX operating temperatures	<-- Equivalent Operating Condition														
Exposed Fire Area [ft ²]	SL Volume [ft ³]																			
100.0	2.00																			
For BAHX in batteries, PRV sizing guidance is per each individual core																				
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Conditions for Operating Without an Active Smart Layer™ Connection

A core equipped with Smart Layer™ technology may be placed into service without active connections to the SL PRV, SL PT, and SL Charge/Drain connections. When operating in this configuration, ensure the following conditions are met:

1. The SL Charge/Drain connection must have the shipping blind removed and treated like an inactive area vent, leaving the Smart Layer™ stream open to atmosphere.
2. Care must be taken to prevent insulation or other contamination from entering the open SL Charge/Drain connection.
3. The carbon steel shipping blinds on the other two connections (SL PRV and SL PT) must be replaced with materials compatible for operating temperatures.

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™ stream with nitrogen.
4. Disconnect Smart Layer™ stream 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 simultaneously and the high / low pressure alarms will not activate.

If a high-pressure alarm activates:

1. A crack has occurred between the Smart Layer™ stream and a process stream.
2. The Smart Layer™ stream is now “Indicating”.
3. Consider the Smart Layer™ stream 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 the Smart Layer™ stream to confirm leak location. Check the dummy layer vent stubs first.
3. If leak is from vent stubs or BAHX core, the Smart Layer™ stream 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. Continue to monitor the Smart Layer™ stream pressure. If the indication was a high-pressure alarm, then a future drop in Smart Layer™ pressure means an external crack has also developed. If the indication was a low-pressure alarm, then a future rise in Smart Layer™ pressure means a process stream is communicating with the Smart Layer™. In either case, a loss of containment has likely occurred.
6. For low-pressure indications, the user can monitor the growth of the indication leak by one of two methods. A pressure decay test can be run at regular intervals (weekly / monthly / quarterly) and the historic trend can be used to infer if the indication leak is growing. Alternatively, the Smart Layer™ stream can be connected to a regulated pressure supply with a backflow preventer and the flow rate into the Smart Layer™ stream can be monitored for changes. This second method should not be used where perlite insulation is used as turbulent abrasion / erosion can occur.
7. In most instances, Smart Layer™ functionality can be restored after repairs have been made.

Smart Layer™

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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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