Alternatives to Brazed Aluminum Heat Exchangers in Cryogenic Gas Plants

GPA Midstream Convention 2025

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Agenda

- What's the deal with Brazed Aluminum Heat Exchangers (BAHX)?
- Alternatives Considered
  - Shell and Tube Heat Exchangers (S&T)
  - Printed Circuit Heat Exchangers (PCHE)
- Case Study
- Conclusions / Recommendations

A Note of Clarification….

Braised vs Brazed

Braising is a cooking method that combines searing and simmering to tenderize tough cuts of meat. Does not apply to HX.

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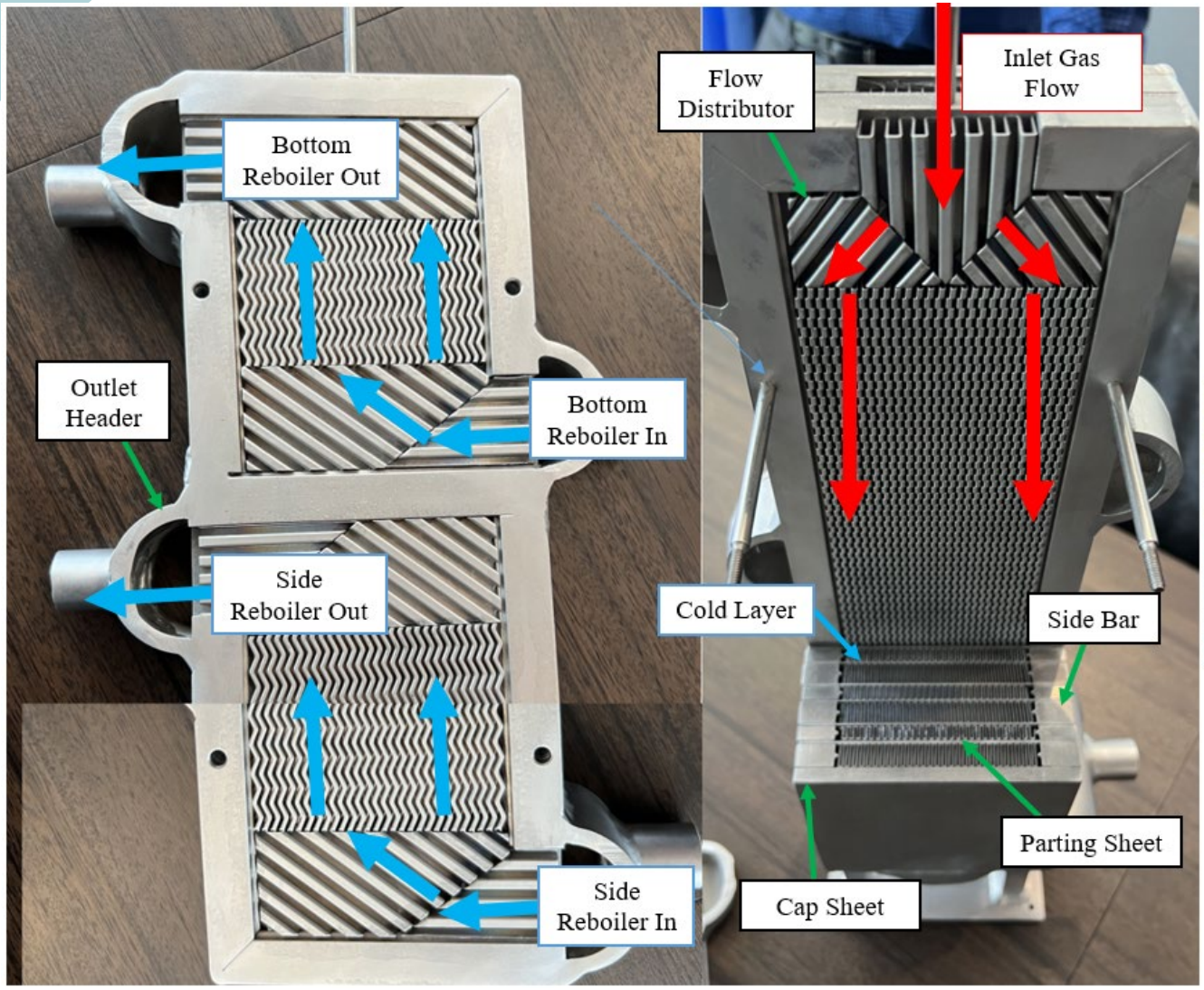
Brazing is a metal-joining process in which two or more metal items are joined by melting and flowing a filler metal into the joint. DOES apply to HX.

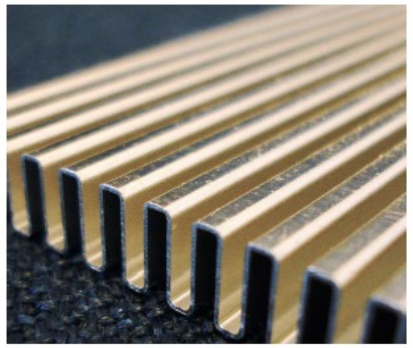
~~Braised~~ Brazed Aluminum Heat Exchanger

What is a BAHX?

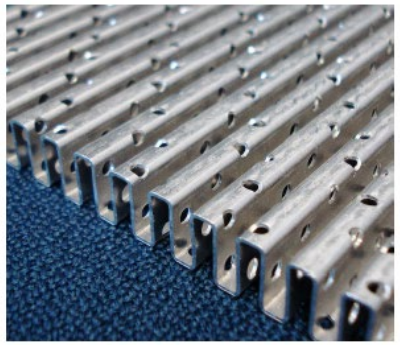
- Compact heat exchangers, sometimes also referred to as “Plate-Fin Exchangers”
- A “core” is made by stacking layers of corrugated fins separated by parting sheets
- The “core” is brazed in a furnace and sealed along the edges with side and end bars.
- Headers and nozzles are welded onto the brazed core
- Up to 10 streams in single unit
  - Counterflow
  - Crossflow

BAHX – A look inside

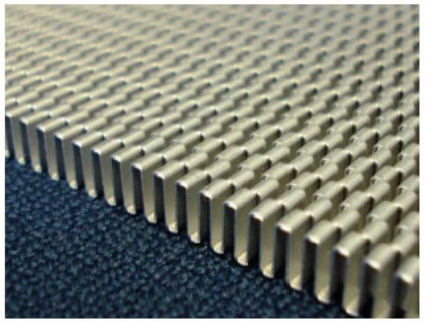




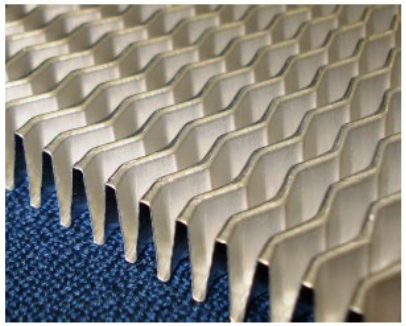
Plain fins



Plain-perforated fins



Serrated fins



Herringbone or wavy fins

Fin picture: Images are from the ALPEMA 4th Edition (copyright)

BAHX in Midstream

- **Widely accepted as most economic heat transfer technology for cryogenic NGL recovery facilities**
- **Benefits**
  - High rates of heat transfer due to aluminum construction
  - Greater heat transfer surface area density

  } Tight approach temperatures (2-4°F)

  - Compact design / less plot space
  - Less weight
  - Low relative cost
  - Able to handle cryogenic temperatures
- **Disadvantages**
  - Limited to 150°F due to strength of aluminum
  - Susceptible to thermal fatigue
  - Prone to plugging
  - Aluminum is susceptible to mercury attack
  - Lead times
  - Limited domestic suppliers

BAHX at Phillips 66

- Phillips 66 operates over 30 cryogenic gas plants in Midstream
  - Over 20 of these plants have BAHX
  - ~30% of plants with BAHX have experienced leaks at some point (some OOS)
  - Most failures have been observed in two phase services (bottom and side reboilers)

Causes of Failure in BAHX

- **Thermal fatigue**
  - Temperature rate of change
  - Temperature differential
  - Maldistribution (fouling)

ALPEMA Recommendations:

- 90°F max dT b/t adjacent single phase streams in SS operation
- 36-54°F max dT b/t adjacent two-phase or cyclic streams in SS operation
- ±1.8°F/min max rate of change in SS operation
- ±9°F/min max rate of change in transient operation and not to exceed 108°F/hour

Transient operation:

- Startup / Shutdown
- Switching modes (recovery / rejection)
- Warmup / Cooldown

- **Ice formation**, most notably from pockets of water
- **Chemical attack**
  - Mercury: < 0.1 micrograms/Nm3 (12.2 parts per trillion (ppt)) mol Hg/mol gas

Source: The Standards of The Brazed Aluminium Plate-Fin Heat Exchanger Manufacturers' Association, 4th edition, 2024
ALPEMA® IOW for BAHX June 2025

Conditions Leading to Thermal Fatigue

Unstable thermosyphon hydraulics (slug flow)

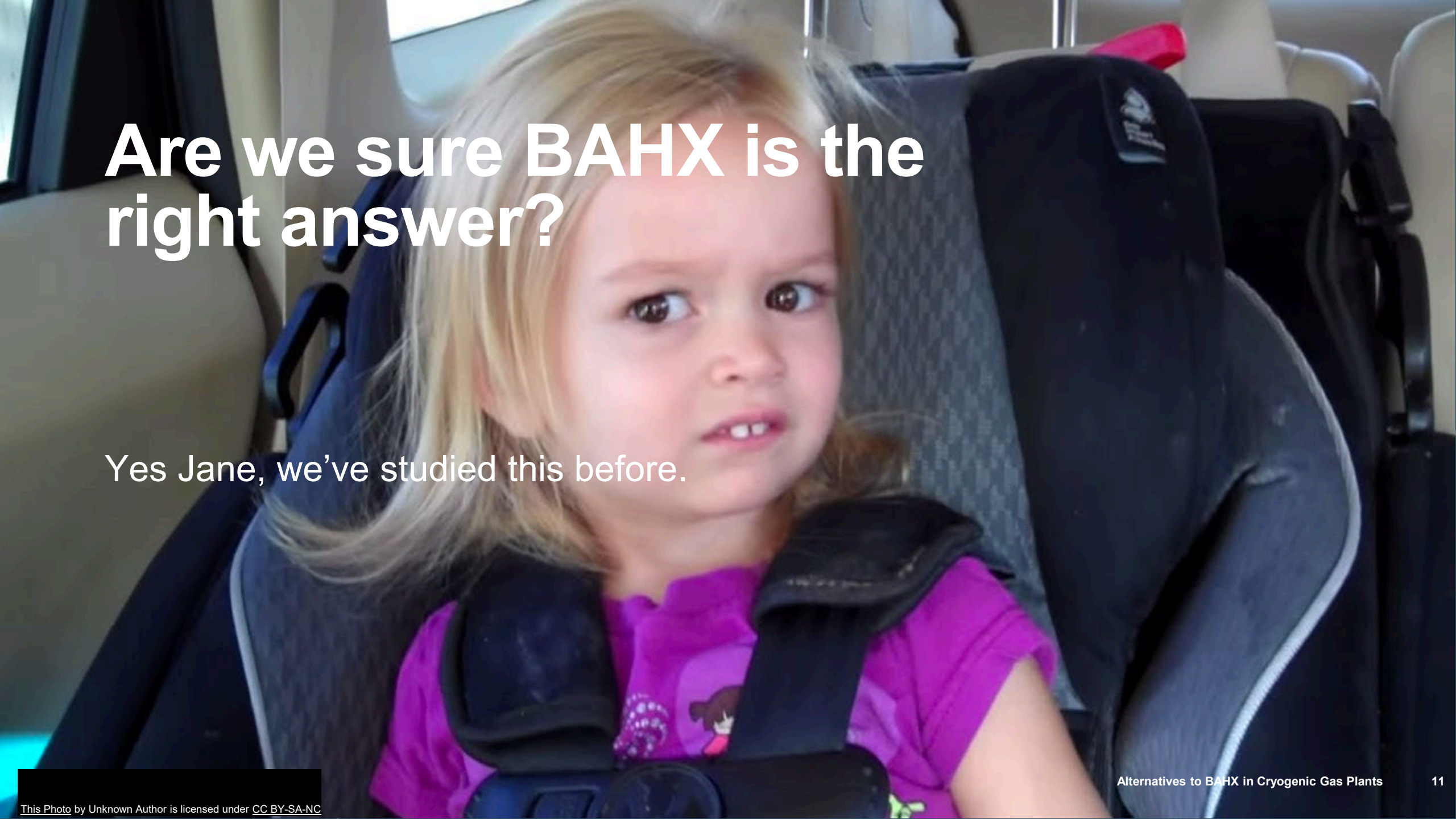
Operation outside of design conditions

- Flow
- Composition

Swinging operations (rejection to recovery)

Are we sure BAHX is the right answer?

Yes Jane, we've studied this before.



Alternative 1: Shell and Tube Heat Exchanger (S&T)

- **Benefits**
  - More suppliers
  - More familiarity
  - Shorter delivery times
  - *Not prone to thermal fatigue (with appropriate design measures)*
  - *Integrity not as impacted by off design operation*
  - *No design temperature limitations in this service with right metallurgy*
  - *Not susceptible to plugging or mercury*

- **Disadvantages**
  - Plot space
  - Lowest heat transfer efficiency of options considered in evaluation
  - Weight
  - Cost

Alternative 2: Printed Circuit Heat Exchanger

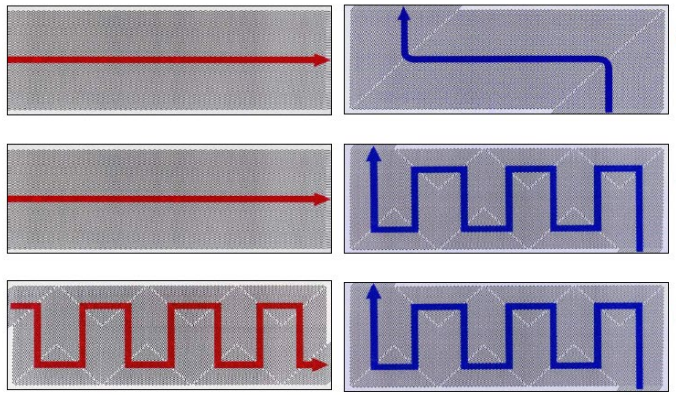
What is a Printed Circuit Heat Exchanger (PCHE)?

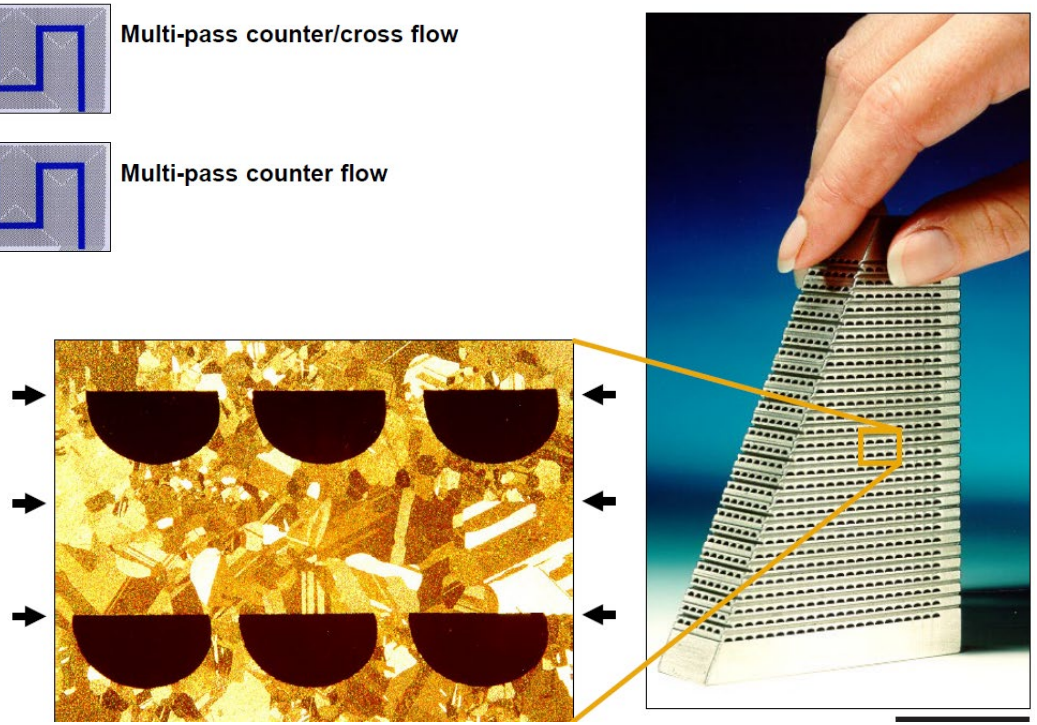
PCHE are compact HX that are formed by diffusion bonding of chemically etched plates to form a solid core block.

- Flow channels are chemically etched only a plate
- Etched plates are stacked for diffusion bonding
  - No braze or filler
  - Metal grain growth
- Standard plate sizes (height x width)
- Maximum dimensions for a single block (height x width x length)
- Multiple blocks can be welded together to form a core (length * x)

Content courtesy of Heatric (Parker Hannifin)

Plate Detail





Micrograph of a bonded core section
(Arrows indicate the original plate surface locations)

Images courtesy of Heatric (Parker Hannifin)

PCHE Components

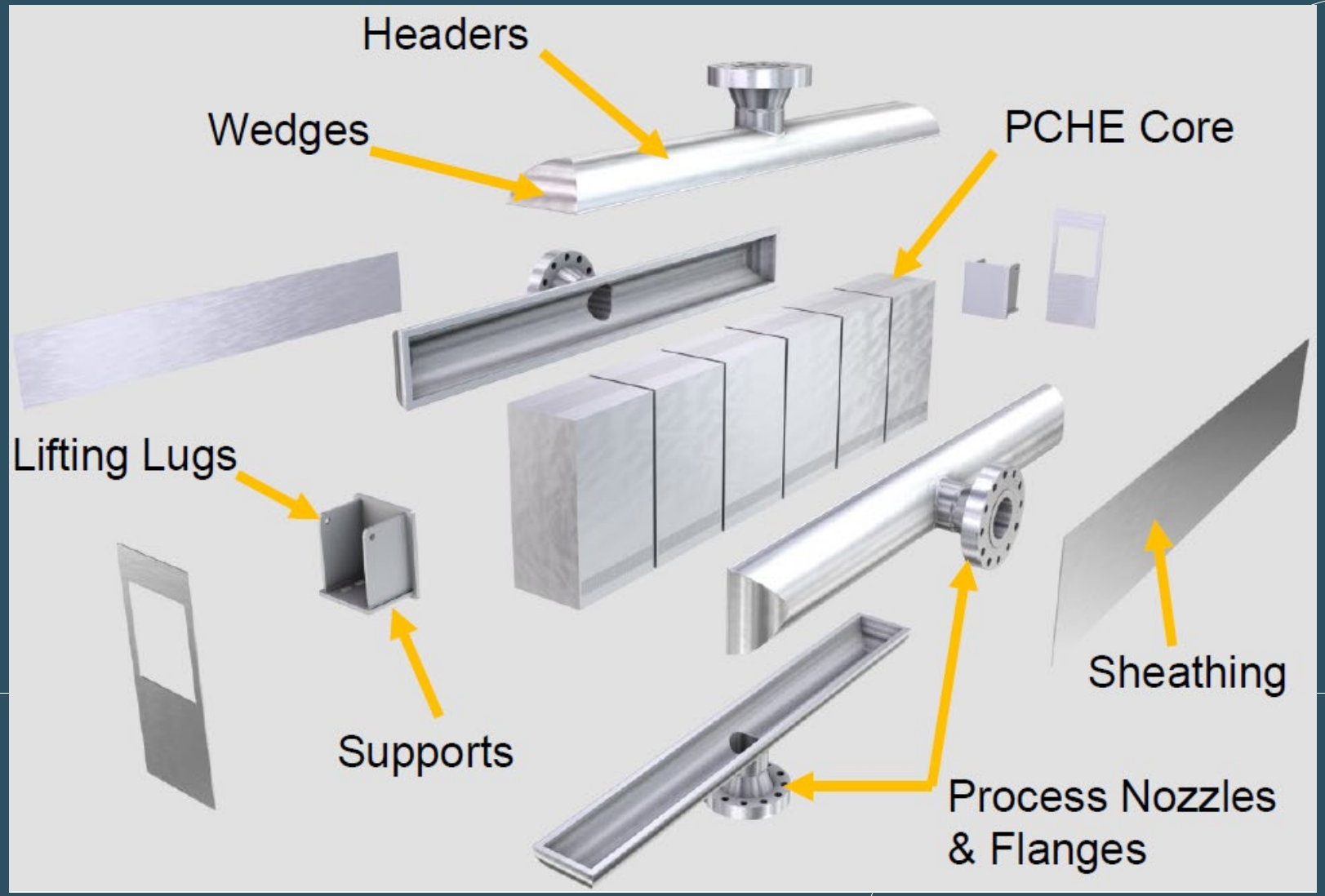


Image courtesy of Heatric (Parker Hannifin)

PCHE

- **Benefits**
  - Higher rates of heat transfer than S&T
  - Greater heat transfer surface area density than S&T
  - Compact design / less plot space
  - Able to handle high pressures and temperatures
  - *Less susceptible to thermal fatigue vs BAHX*
  - *Integrity not as impacted by off design operation*
  - *Not susceptible to mercury attack*

} Tight approach temperatures (5-9°F)

- **Disadvantages**
  - Unfamiliar to Midstream
  - Limited experience in NGL recovery plants
  - Lead times
  - Limited suppliers
  - Risk of plugging
  - Cost

S&T vs PCHE

Shell & Tube: 108 tonnes
PCHE: 15 tonnes

(Identical design & process conditions)

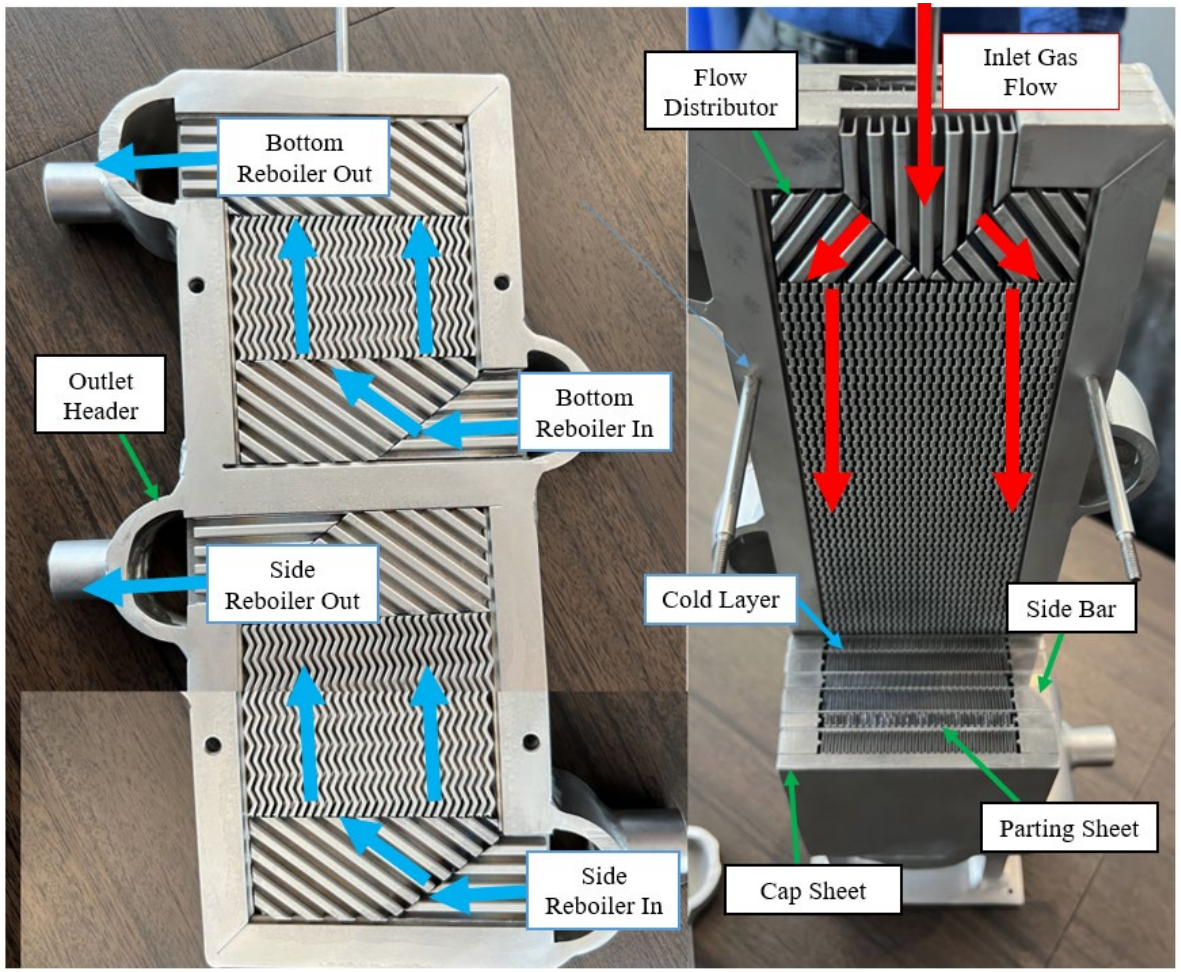
Image courtesy of Heatric (Parker Hannifin)

PCHE Example

Image courtesy of Heatric (Parker Hannifin)

PCHE in Demethanizer Side / Reboiler Service

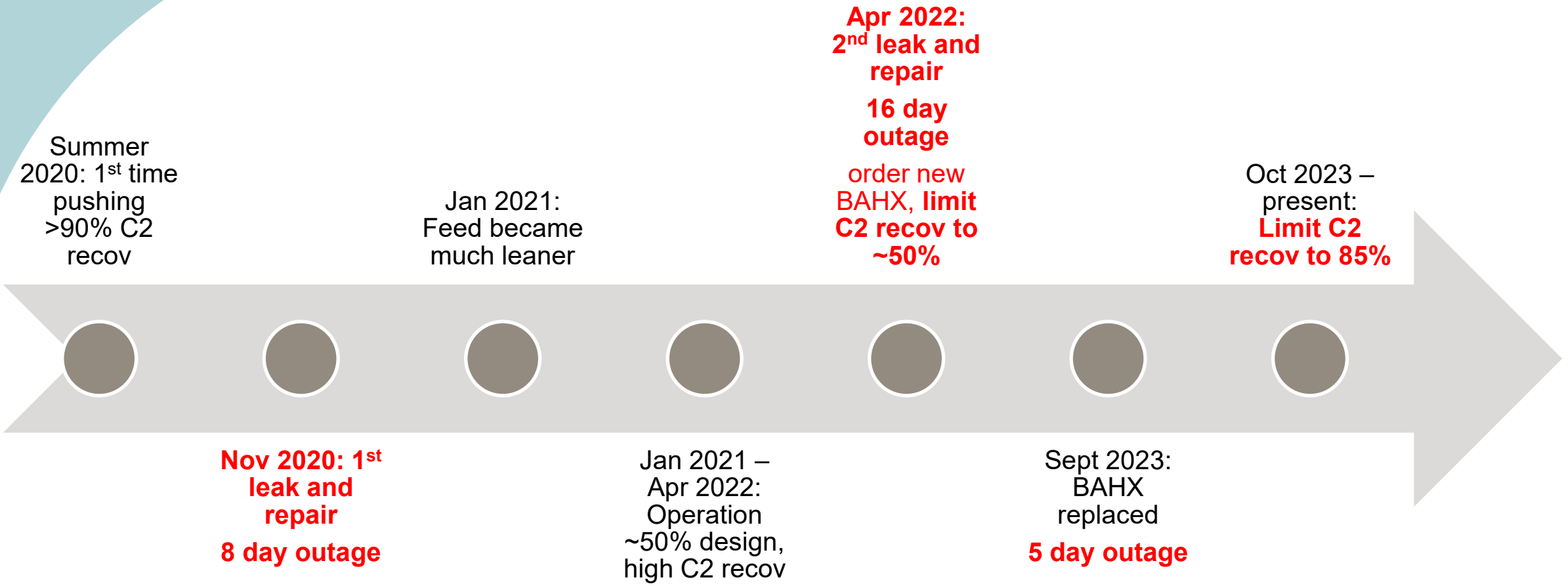
Case Study



Repeated Failures of BAHX in 200 MMSCFD Gas Plant

Reboiler / Side Reboiler

Timeline



Every outage and recovery limit: lost profit opportunity

Evaluation of Options

CASES CONSIDERED

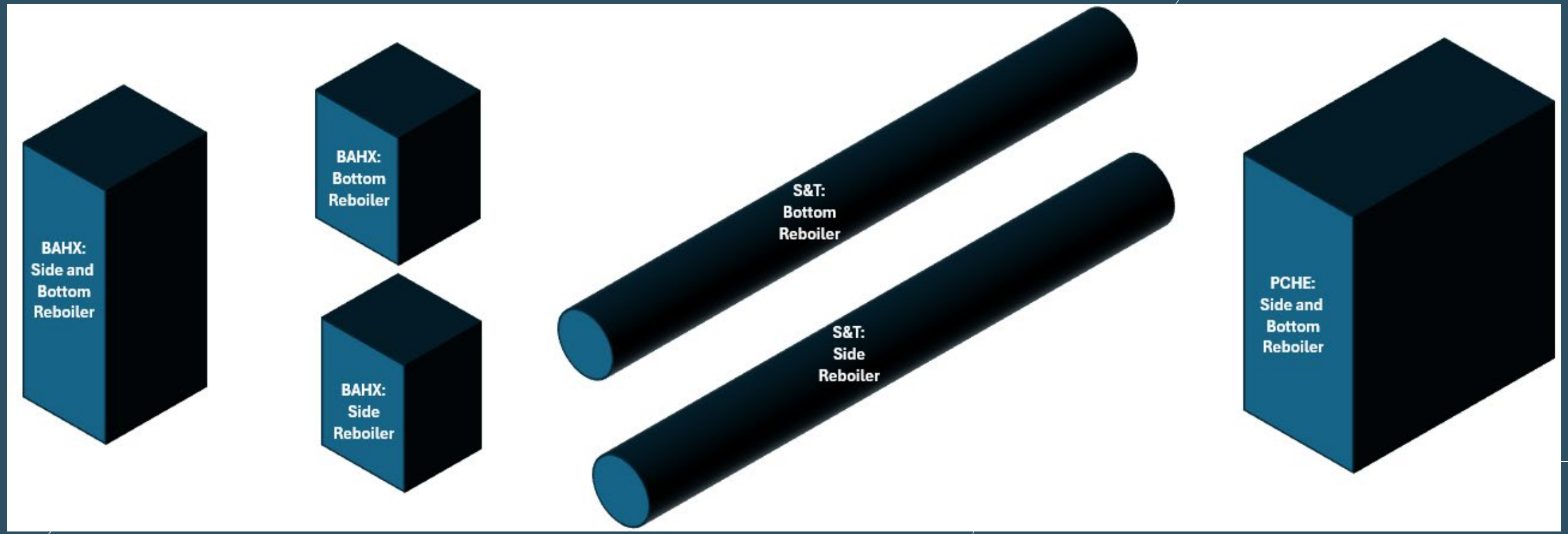
1. Maintain BAHX design, limited C2 recoveries to 85%
2. Maintain BAHX design, maximize C2 recoveries
3. Separate reboiler and side reboiler BAHX
4. Replace BAHX with S&T
5. Replace BAHX with single, stacked PCHE

BASIS

- 5 year operating period considered
- Determined FEL-0 level TIC using factor for installation costs
- 2 week outage for any new HX design
- Quotes for S&T and PCHE based on original H&MB without sacrificing approach temperature
- Repairs
  - Used historical data for Case 2
  - Assumed 50% of historical for split BAHX case
  - Assumed no repairs req'd for other cases

Physical Comparison

Heat exchangers only



Relative Comparison of Options

5 year operating period

	Maintain BAHX Design Reduced C2 Recovery	Maintain BAHX Design Max C2 Recoveries	Separate BAHX	Shell and Tube	Printed Circuit Heat Exchanger
Delivery*	65 weeks	65 weeks	65 weeks	30-34 weeks	~60 weeks
Weight (HX only)	1	1	0.9x	3.4x	1.4x
Cost					
Initial TIC incl downtime	0	0	1.5	2.5	2.0
Losses / Repairs	7.5	2.1	0.9	0	0
TOTAL	7.5	2.1	2.4	2.5	2.0

Note – Design optimization could meaningfully change the comparison

* Deliveries shown were at the time they were quoted. Expected to be different if quoted today.

Technology Comparison

General – Design optimization could meaningfully change the comparison

	BAHX	S&T	PCHE
Reasonable Min Approach Temp, °F	2-4 °F	15-30 °F	5-9 °F
Relative Equip Cost (not including install)	1	1.5-2x	3x
Relative Weight	1	3.4x	1.4x
Advantages	• Compact • Low cost • Heat transfer efficiency • Weight	• Shorter delivery times • More suppliers • Not prone to thermal fatigue • Integrity not meaningfully impacted by off design operation • High design temperatures	• Compact • Less susceptible to thermal fatigue • Integrity not meaningfully impacted by off design operation • High design temperatures • Better heat transfer efficiency that S&T
Disadvantages	• Long lead time • Limited domestic suppliers • Integrity suffers with off design operation • Prone to plugging • Susceptible to mercury attack • More susceptible to damage from ice • Limited to 150°F	• Plot space • Lowest heat transfer efficiency, could impact refrig load or recoveries • Weight	• Unfamiliar technology to midstream • Cost • Long lead time • Limited suppliers • More at risk of plugging than S&T

When to Consider Alternative Heat Exchangers

Brownfield

- Failure(s) of the BAHX has occurred and
  - Conditions / physical design cannot be adjusted to avoid thermal fatigue
  - The composition or throughput will continue to differ from the original design
  - Regular upsets / transients cannot be avoided
- Alternatively could consider a spare BAHX

Greenfield

- BAHX in reboiler service and….
- It is planned to be a swing plant
- It is known that compositions will vary over time
- The plant may not always operate at design capacity
- Upsets / transients from sources upstream of the cryo unit are anticipated and cannot be avoided
- Strong desire to minimize risk

Note: circumstances leading up to most failures were not anticipated at start of project

If none of these circumstances apply to your application,
BAHX is still an excellent choice for cryogenic NGL recovery plants.

Acknowledgements

Jake Carrier, Phillips 66
Heatric (Parker Hannifin)

Thank you for your time!

Questions?

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