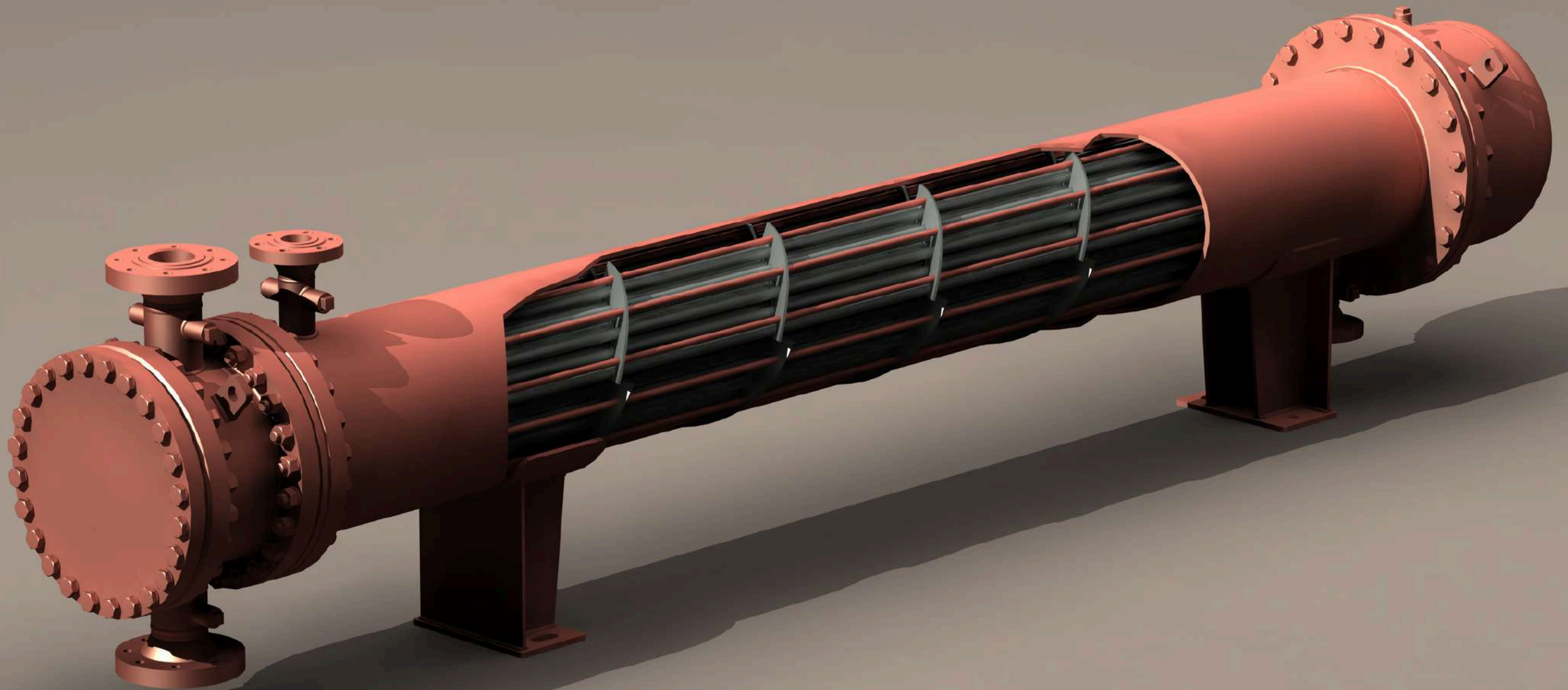


XCHANGER XPRESS



IN THIS ISSUE



Innovative Design: Transforming Heat Exchanger Performance in Refineries

Insights from PECPL Industrial Experience

Shell-and-tube heat exchangers (STHXs) play a vital role in refinery processes; however, traditional segmental baffle designs often encounter issues such as significant pressure drops, fouling caused by flow, and suboptimal thermal efficiency. A prominent refinery located in South India dealt with ongoing shell-side fouling and expensive maintenance for their fixed type or U type of exchanger associated with the Vapor Recovery Unit (VRU) beneath the Crude Distillation Unit (CDU). The fixed tube sheet design has NO access for the shell side cleaning, leading to frequent shell assembly replacements and increased operational downtime. To tackle these issues, PECPL, in partnership with Lummus Heat Transfer (LHT), performed a comparative assessment of three TEMA configurations: fixed or U type, AES (segmental Baffle), and AES Helix. The design of the AES Helix incorporates quadrant-shaped baffles set in a helical arrangement, which eliminates compartmentalization and facilitates uniform distribution of fluid on the shell side without dead zones. The performance evaluation indicated that the AES Helix achieved a required shell-side velocity and a higher outlet temperature removing the necessity for a separate boiler and lowering both capital and operational costs. The AES Helix heat exchanger introduces a highly efficient design that significantly improves operational performance in refinery applications. Its helical baffle configuration creates an optimized flow path that minimizes pressure losses and eliminates dead zones, which in turn reduces the risk of fouling and simplifies cleaning during maintenance.

Compared to conventional shell-and-tube designs, AES Helix delivers superior heat transfer efficiency and long-term reliability. This innovation offers a compelling combination of high performance, ease of upkeep, and cost-effectiveness, making it a valuable solution for modern heat transfer challenges in industrial settings. PECPL provides cutting-edge technologies that enable enhanced operational excellence.

1. INTRODUCTION

Heat exchangers are the key component in different industries such as power generation, food industry, process industries, oil refining, etc. In particular, the shell and tube heat exchanger (STHX) is considered the most popular type, accounting for more than 40 % of operations.

A Heat Exchanger may be defined as an equipment which transfers energy from a hot fluid to a cold fluid, either maximum or minimum rate within minimum investment and running cost [1]. In this process never two fluids mixed with each other. This device provides a flow of thermal energy between two or more fluids at different temperatures. Shell and tube heat exchangers are the most versatile type of heat exchanger; they are used in a wide variety of engineering applications like power generation, waste heat recovery, manufacturing industry, air conditioning, refrigeration, space applications, petrochemical industries etc.

Shell and tube type heat exchanger (STHE) consists of a bundle of tubes enclosed in a cylindrical shell, one fluid passes through the tubes and second fluid flows between the tube and shells. STHE has large heat transfer efficiency in comparison with others. Shell and tube heat exchangers with segmental straight baffles have low heat transfer Co-efficient due to the segmental straight baffle arrangement causing high leakage flow by passing through the heat transfer surface and high pressure drop that causes a big problem for industries as the pumping costs increases.

There are several proposed approaches to enhance the effectiveness of the STHX, in which numerous designs have been developed in which the flow is longitudinal and helical to decrease the flow stagnation created by the baffles. Using the helical baffles is one of the alternative approaches, in which the helical baffles are the most commonly used as they create more flow turbulence, reducing the pressure drop and increasing the heat transfer rate[2].

During the past few decades, much research work has been done on predicting and improving performance of heat exchangers. The helical baffle was first invented in 1990 by Luřcha and Němĉanský in Czechoslovakia and commercialised by ABB Lummus Heat Transfer in USA. As the most promising baffle design, carried out a comprehensive study on overlap helical baffles, which is the first helical baffle [3]. They found the helicoid flow pattern in the shell-side. Helical baffles enhance heat exchanger performance by forcing a continuous helical fluid flow, which increases heat transfer rates, reduces pressure drop, prevents flow-induced vibration, and minimizes fouling. This design offers significant advantages over traditional segmental baffles, leading to smaller equipment sizes, reduced capital and operating costs, and improved plant reliability [5]. The three types of STHX previously mentioned, including single segmental baffle (SG-STHX), continuous helical baffle (CH-STHX), and alternative inclined baffle (XX-STHX) are shown in Fig 1.

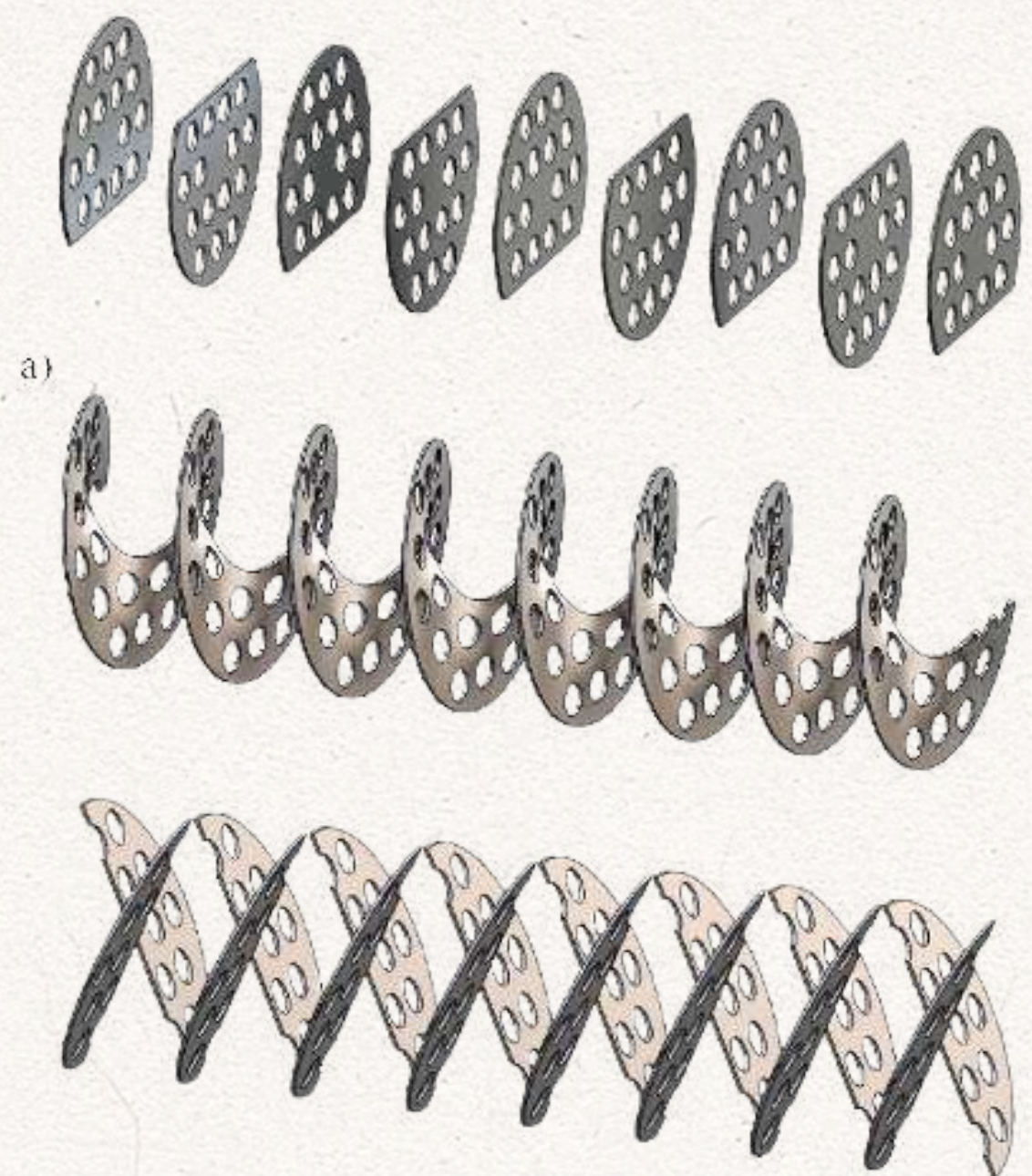


Fig 1. Shell-and-tube heat exchanger's baffles: a) SG-STHX, b) CH-STHX, c) XX-STHX

To find the angle of baffles:

helix angle (α) is:

$$\alpha = \arctan(\text{Lead} / (\pi \times \text{Diameter}))$$

$$\therefore C = \pi \cdot D$$

1. Lead (L): This is the linear distance the thread or helix travels along the axis for one complete turn.
2. Diameter (D): This is typically the pitch diameter of the thread or gear, or an average of the major and minor diameters.
3. Helix Angle (α): Take the inverse tangent (arctan) of the value you found in the previous step to get the helix angle in radians.

4. Circumference (C): Multiply the diameter by pi ($\pi \approx 3.1416$).

As part of our ongoing mission to deliver innovative solutions to refinery challenges, PECPL, in collaboration with Lummus Heat Transfer (LHT), conducted a strategic three-day engagement across the south of India. The objective: identify the bad actors at major refineries and demonstrate how Helix technology can revolutionize performance. Our discussions with technical and operations teams highlighted recurring challenges such as fouling, downtime, and reduced efficiency. The overwhelmingly positive reception to our Helix presentations reaffirmed its potential as a game-changing solution for the industry [6]. The novel XX-STHX model, there are 8 similar structures arranged consecutively as shown in Fig. 2.



Fig 2. Structure of a Couple of baffles in XX-STHX.

2. MATERIALS AND METHODS

2.1 CASE SPOTLIGHT

This case study compares three common TEMA heat exchanger configurations — Fixed Tube Sheet / U-type, AES conventional, and AES Helix. The comparison highlights differences in maintenance, fouling resistance, thermal performance, and cost, to help engineers select the right configuration for refinery and process applications [7].

Date: 31st July 2024 Client: Leading South India-Based Oil Manufacturer Application: Vapor Recovery Unit (VRU) under Crude Distillation Unit (CDU) Existing Design: Stabilizer Feed Bottom Exchanger – TEMA Type fixed or U type.

In the CDU, the Vapor Recovery Unit (VRU) captures light hydrocarbon vapours mainly propane, butane, and other light end from vent streams, condensers, and storage tanks. These vapours are compressed and cooled to recover LPG, which is reused or sold. This process reduces VOC emissions and enhances safety by preventing flammable vapor buildup.

Integrated with the VRU is the naphtha stabilizer system. The Stabilizer Feed/Bottoms Exchanger transfers heat from hot stabilized bottoms (170–195°C) to cold unsterilized feed, preheating it to 100–125°C. This improves separation efficiency in the stabilizer column and reduces the load on the reboiler.

The reboiler vaporizes 20–40% of the bottom liquid to strip lighter hydrocarbons and maintain column temperature. This heat integration lowers steam consumption and improves energy efficiency.

The exchanger also cools stabilized bottoms from ~140°C to 70–90°C before storage, preventing degradation and ensuring RVP compliance for safe handling.

Together, the VRU and exchanger form a smart, energy-efficient system that boosts product quality, reduces emissions, and supports modern refinery performance.

2.1.1 CHALLENGE

The client experienced severe shell-side fouling in their fixed-type or U-type exchanger, handling ‘Stabilized Bottom’ (shell side) and ‘Unstable Naphtha’ (tube side). Due to the fixed tube sheet design, frequent and costly replacements were required.

2.1.2 CLIENT’S INITIATIVE

To reduce maintenance costs, the client’s team proposed a shift to TEMA Type AES configuration with a floating head for easier maintenance.

2.1.3 PECPL’S ROLE

The client initially explored a Two-Shell AES design to address maintenance challenges and improve thermal performance. However, concerns regarding design complexity and spatial constraints led them to consult PECPL for a more practical solution. In collaboration with Lummus Heat Transfer (LHT), PECPL developed a customized single-shell AES Helix configuration tailored to the application.

This optimized design simplifies maintenance through improved accessibility, minimizes fouling risk by promoting uniform flow distribution, enhances thermal efficiency via helical fluid dynamics, and significantly reduces the overall operational footprint. The result is a high-performance, space-efficient exchanger that meets the client's technical and operational goals.

2.2 PERFORMANCE EVALUATION: AES (STACKED) SEGMENTAL VS. AES HELIX

A comparative study was conducted to evaluate the performance of three shell-and-tube heat exchanger configurations: the Two-Shell AES (Floating Head) design with segmental baffle, and the advanced AES Helix design. Table 1 shows the performance evaluation of AES segmental and AES helix.

| DESCRIPTION | AES (TWO-SHELL) | AES (HELIX) |
|----------------------------|-----------------|-------------|
| Shell Side Velocity (m/s) | 0.7 | 1.33 |
| Shell Outlet Temp (°C) | 107 | 119.23 |
| Tube Side Outlet Temp (°C) | 121 | 121 |
| Δ P kg/cm2 | 0.3 | 0.3 |

Table 1. The performance evaluation of AES stacked and AES helix.

2.2.1 COST COMPARATIVE: AES (STACKED) SEGMENTAL VS. AES HELIX

A 20-year comparative study between AES Stacked and AES Helix exchangers shows a clear edge for the AES Helix design. While both exchangers provide the same duty and design life, the Helix requires only six maintenance interventions over the study period, compared to forty for the conventional Stacked model. This significant reduction in maintenance leads to lower downtime, reduced overall expenditure, and enhanced long-term operational efficiency.

Although the Helix exchanger carries a higher initial purchase cost, its substantially lower maintenance requirements result in a considerably reduced life-cycle cost. Overall, the investment delivers more than 2.5 times return on the incremental cost.

Based on these findings supported by the comparative price assessment (Table 2) and illustrated through 3D models of both exchanger types (Figures 3 and 4) the AES Helix exchanger is recommended as the more economical and operationally efficient solution for long-term use.

| DESCRIPTION | CONVENTIONAL (AES STACKED) | HELIX EXCHANGER AES |
|--|----------------------------|---------------------|
| Purchase Cost (USD) [A] | \$67,620 | \$112,700 |
| Planned Cleaning & Maintenance Frequency (Month) | 6 | 36 |
| Cleaning & Maintenance Costs Each Time (USD) [B] | \$4,508 | \$4,508 |
| Duration of Event (days) | 3 | 3 |
| Number of Events During Exchanger Design Life for 20 years [C] | 40 | 6 |
| Process Utilization (% of Total Annual Production at Design Capacity) | 95% | 95% |
| Design Duty (MM Kcal /HR) | 2.94 | 2.94 |
| Design Life of Exchanger (years) | 20 | 20 |
| Life Cycle Cost of Exchanger (USD) [D] = [A+(B*C)] | \$247,900 [D1] | \$139,800 [D2] |
| Life Cycle Benefit of HELIXCHANGER vs Conventional Exchanger [E] = [D1-D2] | \$108,200 | |
| Life Cycle Return on Incremental Cost of HELIXCHANGER | >2 times | |

Table 2. The comparative estimation of price impact

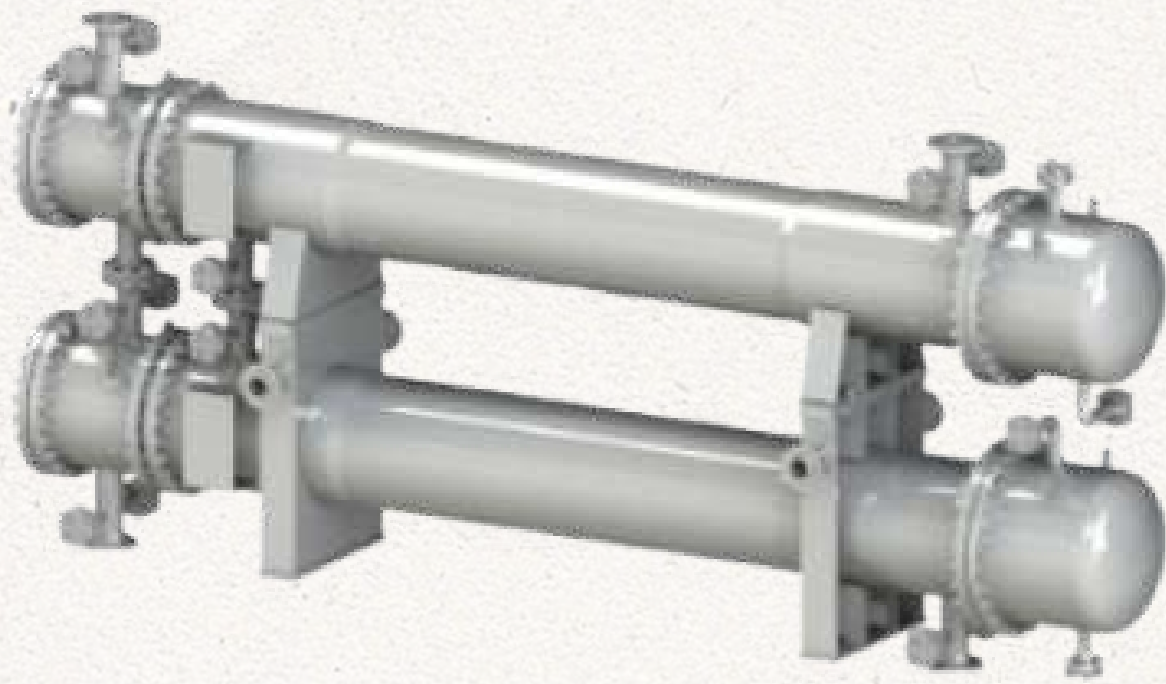


Fig 3. AES Stacked Exchanger

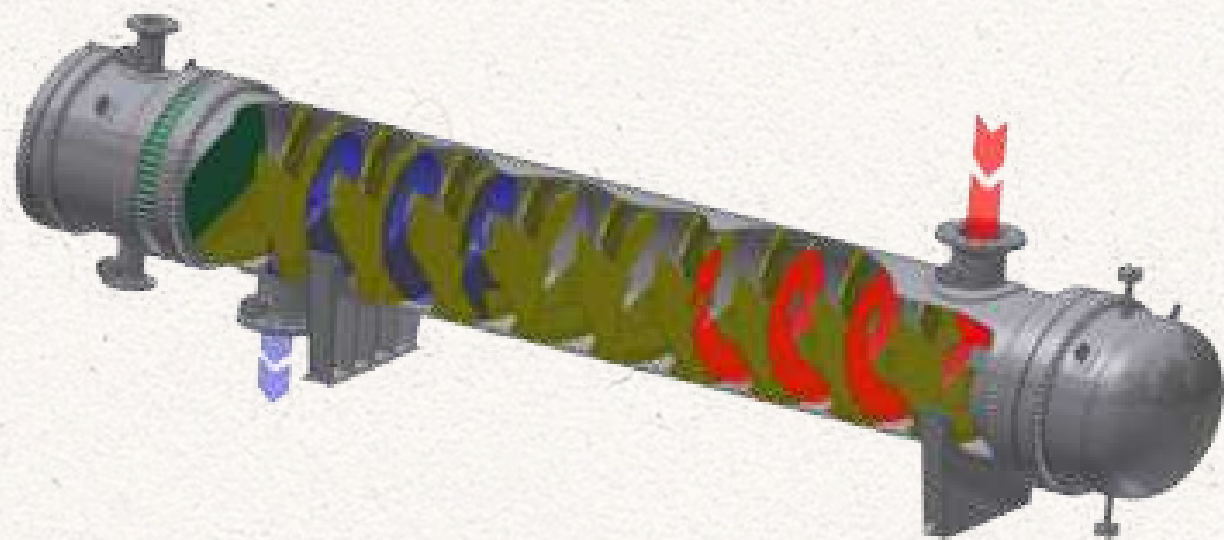


Fig 4. AES Helix Exchanger.

1.A. Conventional Exchanger (AES Stacked)

- Purchase Cost = \$67,620
- Maintenance Cost per Event = \$4,508
- Number of Events in 20 Years = 40

Life Cycle Cost (D1)

$$D = A + (B \times C)$$

$$D1 = 67,620 + (4,508 \times 40)$$

$$D1 = 67,620 + 180,320$$

$D1 = 247,940 \text{ USD}$

B. Helix Exchanger (AES Helix)

- Purchase Cost = \$112,700
- Maintenance Cost per Event = \$4,508
- Number of Events in 20 Years = 6

Life Cycle Cost (D2)

$$D = A + (B \times C)$$

$$D2 = 112,700 + (4,508 \times 6)$$

$$D2 = 112,700 + 27,048$$

$D2 = 139,748 \text{ USD}$

2. Life Cycle Benefit of Helix Over Conventional

$$E = D1 - D2$$

$$E = 247,940 - 139,748$$

$E = 108,192 \text{ USD}$

3. Return on Incremental Cost

Incremental Cost of Helix Exchanger

$$\text{Incremental Cost} = 112,700 - 67,620$$

$$= 45,080 \text{ USD}$$

Return on Incremental Cost

$$\text{Return Ratio} = \frac{E}{\text{Incremental Cost}}$$

$$\text{Return Ratio} = \frac{108,192}{45,080}$$

$\text{Return Ratio} \approx 2.4 \text{ times}$

2.2.2 KEY FINDINGS

The AES Helix design demonstrated clear performance advantages over both conventional fixed or U-type and standard Two-Shell AES configurations. It achieved a shell-side velocity of 1.33 m/s—nearly twice that of the Two-Shell AES at 0.70 m/s—indicating more effective fluid movement and enhanced heat transfer. Additionally, the AES Helix delivered a higher shell-side outlet temperature of 119.23°C compared to 107°C in the Two-Shell AES, eliminating the need for a separate boiler and contributing to significant energy and cost savings. These improvements reflect the exchanger’s superior thermal efficiency, reduced pressure drop, and optimized flow distribution, confirming AES Helix as a high-performance solution for refinery heat transfer applications. The comparative performance matrix shown in Table 3. And graphical representations are shown in Fig 4.

| ASPECT | FIXED TUBE SHEET | AES – CONVENTIONAL (STACKED) | AES – HELIX |
|--------------------------|--------------------------|------------------------------|---|
| Tube Bundle Removal | Not removable | Fully removable | Fully removable |
| Shell-Side Cleaning | Difficult | Easy | Easy |
| Thermal Expansion | Poor | Excellent | Excellent |
| Fouling Resistance | Low | Medium | High |
| Heat Transfer Efficiency | Moderate | Good | Excellent |
| Pressure Drop | Moderate | Higher | Lower (optimized flow) |
| Cost | Low | High | High (but better lifecycle economics) |
| Applications | Clean, low-duty services | Fouling, high ΔT duties | Energy-critical, fouling-prone services |

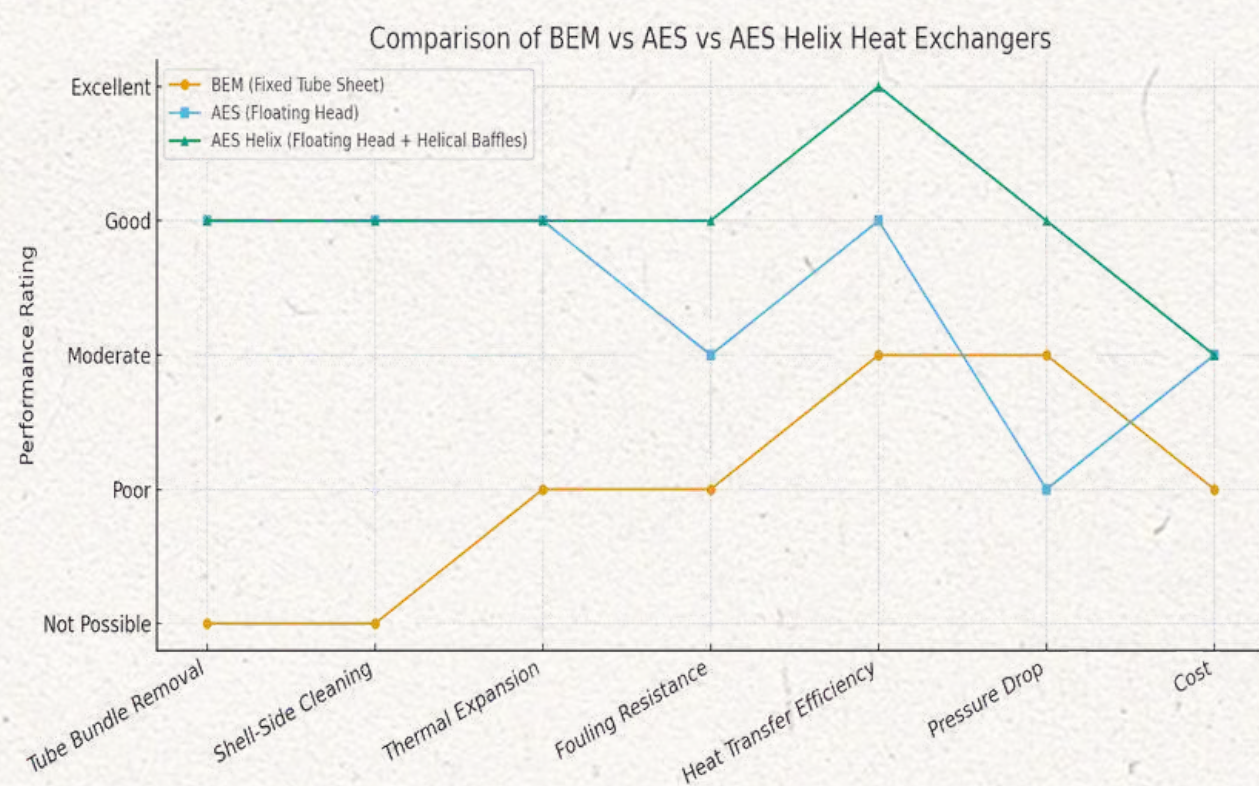


Fig 4. graphical representations of Performance Rating.

RESULT

During the client review, a breakthrough insight emerged: the AES Helix solution's ability to deliver a higher shell-side outlet temperature effectively eliminated the need for a boiler that was previously required to boost the process stream temperature. This advancement not only simplified operational workflows but also resulted in substantial savings in both capital investment and recurring expenses. The successful implementation of AES Helix underscores its transformative impact on refinery operations driving down maintenance costs, improving energy efficiency, and enhancing operational flexibility. These benefits collectively enable more reliable performance, optimized resource utilization, and agile responsiveness to evolving production demands. PECPL remains committed to partnering with refineries to address complex heat transfer challenges and unlock new levels of operational excellence

CONCLUSION

The Helix Changer design represents a significant advancement over conventional segmental baffle shell-and-tube exchangers by addressing their core inefficiencies. Through its innovative helical flow path and quadrant-shaped baffle segments, it eliminates compartmentalization, minimizes flow leakage, and prevents dead zones resulting in superior thermal performance, reduced pressure losses, and enhanced reliability. This optimized flow architecture not only improves heat transfer effectiveness but also contributes to lower fouling risk and extended equipment life, making it a compelling solution for demanding industrial applications [8].

The proposed single-shell-pass shell-and-tube heat exchanger with alternative inclined baffles (Helix) presents a compelling advancement over conventional SG-STHX and CH-STHX designs. By employing interlocked semi-elliptical baffle segments arranged in a crossed pattern, the design enables spiral flow that minimizes dead zones and ensures uniform shell-side fluid distribution. This results in improved thermal efficiency and reduced pressure drop, while its simplified baffle geometry offers a practical manufacturing advantage over more complex helical configurations. The innovation strikes an effective balance between performance and cost, making it a promising solution for enhanced heat exchanger design.

For any doubts, clarifications, additional requirements, or support needed to enhance the efficiency of the equipment, please feel free to reach out to us, please contact theva@pecpl.com or dhakshnamoorthy@pecpl.com.

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