DEVELOPMENTS IN HEAT EXCHANGERS TECHNOLOGY USED IN THE PETROLEUM & GAS INDUSTRIES

Mohand Amokrane MASRI

Algerian Petroleum Institute –Spa/Sonatrach, Boumerdes 35000, Algeria

Email: mohand.masri@iap.dz

Résumé - Au début de l'ère pétrolière, la commercialisation du pétrole fut par des sociétés qui exploitaient les gisements en échange d'une redevance aux pays propriétaires. De nos jours, ce sont les pays pétroliers qui ont pris en charge ce maillon de la chaîne pétrolière.

Pour assurer une plus grande concentration de l'offre, condition indispensable au succès d'une bourse de matières premières, le marché pétrolier international se divise en trois grandes régions (Europe, Amérique et Asie). Quelques qualités de bruts comme le Brent, le WTI ou le Dubaï deviennent les principales références pour les transactions respectivement dans l'Europe, l'Amérique et l'Asie.

Le prix du brut est la combinaison complexe de trois déterminants : fondamentaux, activités de spéculation et psychologie des acteurs, chacun ayant une importance variable selon les conditions du marché. Les opportunités de spéculation se multiplient : le prix du brut ne dépend plus uniquement des fondamentaux, il est lié à l'activité des spéculateurs et à la psychologie des acteurs sur le marché.

Ce travail s'est proposé d'appliquer la méthodologie de la détermination de prix du brut Algérien "Saharian Blend" sur le marché de Rotterdam.

L'objectif principal de ce travail est de construire un modèle pour la détermination du prix de vente du brut Algérien à destination du marché Européen.

Mots-clefs : Prix de pétrole, brut de référence, produits pétroliers, Sahara Blend.

INTRODUCTION

Heat exchangers are important and wide used equipment in various industries such as oil refining, petrochemical, gas treatment and power generation. Various types of heat exchangers exist. They are used for a wide variety of fluid types with different degree of cleanliness. In the petroleum and gas industries, conventional shell-and-tube heat exchangers are the most commonly used form of exchangers. It accounts for about 42 % of the market share. These exchangers can be constructed in a variety of geometries to operate up to pressure of 400 bars and temperature of 800 °C. The reasons of their wide use in industry are the availability in a wide range of materials, mechanical reliability in service, availability of standards for specification and familiarity with the design.

2. TYPES OF HEAT EXCHANGERS

Different types of heat exchangers, ranging from the conventional shell and tube exchanger to other tubular and

non tubular exchanger of varying degrees of compactness have been developed. In recent years, several developments in heat exchangers technology which improve the performance of shell-and-tube and compact heat exchangers have been made.

For shell-and-tube heat exchangers category, Helically baffled heat exchangers (Helixchanger) as well as other forms of shell-and-tube heat exchangers such as RODbaffle exchangers, EMbaffle exchangers, Twisted tube exchangers with corrugated tubes have been developed and used in several industrial applications.

In the compact category, several types of compact heat exchangers have been developed such as Plate Heat Exchangers (PHE), Spiral Heat Exchangers (SHE), Welded Plate Heat Exchangers (WPHE) and Plate Fin Heat Exchangers (PFHE).

CONVENTIONAL SHELL-AND-TUBE HEAT EXCHANGERS AND THEIR LIMITATIONS

A conventional shell-and-tube heat exchanger consists of round tubes attached to a tube sheet inside a cylindrical vessel. Depending on the application, varying tube sizes, tube lengths

Baffles are used to direct the shell side fluid across the tube bundle as efficiently as possible. The most common type of baffle is the single segmental baffle which changes the direction of the shell-side fluid to achieve cross flow (see Figure 1). There are limitations associated with this type of baffle technology. Disadvantages of segmented baffles include inefficient usage of shell-side pressure drop, dead or low flow zones around the baffles which promote fouling accumulation, corrosion, poor heat transfer and flow induced tube vibration, which can result in equipment failure.

To overcome the limitations of the conventional shell-and-tube exchangers, innovation and developments of new technologies where made.

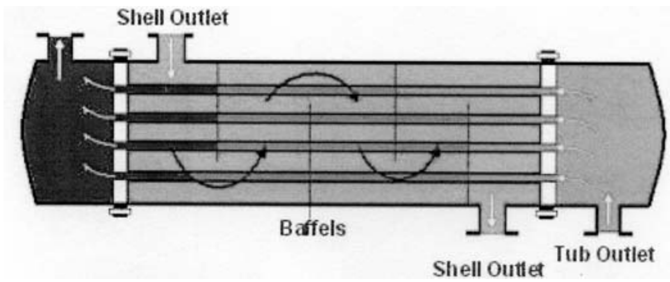


Figure 1: Shell-and-tube-Heat Exchanger

4. DEVELOPMENTS IN SHELL-AND-TUBE HEAT EXCHANGERS TECHNOLOGY

In spite of wide spread acceptance of shell-and-tube exchangers, there are area where further improvements can be made in their performance. Several enhancement techniques have been developed for both shell-side and tube-side. Heat exchanger enhancement can be divided into passive and active methods. Passive methods include extended surfaces, inserts or twisted tubes. Active techniques include mainly vibration and electrostatic fields. Only the passive methods involving mechanical modification to the tubes and baffles are considered in this article.

Shell-side enhancement

The developments for shell-and-tube heat exchangers center around better conversion of pressure drop into heat transfer by improving the conventional baffle designs. The segmental baffle arrangement leads to higher pressure drop due to changing in the direction of flow and dead zones of recirculation which can cause increased fouling. Improvement in the conventional baffle design was the first step in shell-side heat exchangers development. The following developments in shell-and-tube exchanger technology have taken place.

a) Rodbaffle Heat Exchangers

RODbaffle heat exchangers were developed primarily to overcome the problem of flow induced tube vibration. In shell-and-tube heat exchangers, the baffles are constructed from an array of support rod. The support rods are welded at each end to a circumferential baffle ring. A set of four RODbaffles is required to support the tube from all four sides (see Figure 2). Other benefits of using RODbaffles in heat exchangers are lower pressure drop, less fouling and better thermal effictiveness. Several applications of RODbaffle heat exchangers can be found in industry.

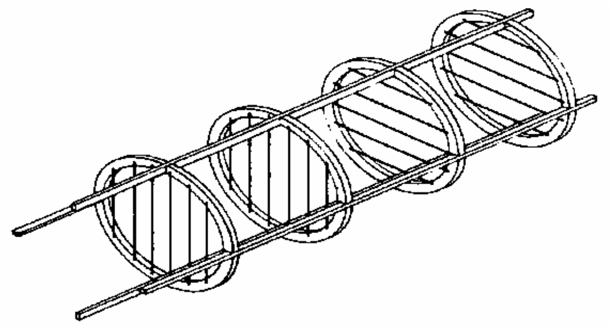


Figure 2: Tube support in RODbaffle Design (source: Phillips Petroleum)

b) Helical Baffle Heat Exchangers (Helixchanger)

One of the advance development in shell-and-tube heat exchangers is the helical baffle exchanger, which employs helical baffles using a special construction [1]. The shell-side flow is helical and along the baffle wall. The dead spaces are eliminated, thereby reducing fouling to a great extent (see Helixchangers can be used efficiently in the petroleum industry to handle viscous fluids with high fouling tendencies. The helically baffle exchanger can contribute to capital cost savings in pumping equipment and reduced power consumption during operation. Helical baffle exchangers have been used to replace conventional segmental baffle exchangers for preheating crude oil in atmospheric distillation unit. It has been reported that the use of helical baffles as a new shells units in retrofit resulted in a pressure drop 26 % lower than in the case of using the conventional baffle system [2]. This substantial decrease in pressure drop results in lower operating costs. Compared to the conventional shell-and-tube exchanger segmental baffles heat exchangers, the Helixchanger offers the following advantages:

Increased heat transfer rate / pressure drop ratio

Reduced bypass effects

Reduced shell-side fouling

Prevention of flow-induced vibration

Reduced pressure drop

Relatively low manufacturing costs.

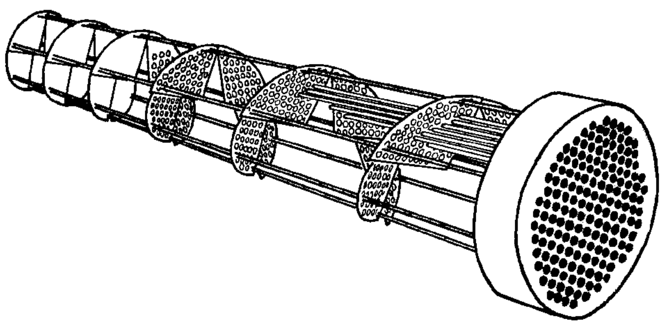


Figure 3- Shell-side helical baffle heat exchanger (source ABB Lummus)

c) EMbaffle Heat Exchangers

The EMbaffle heat exchanger technology has been developed recently to improve performance and reduce operating costs by reducing fouling losses [3]. The EMbaffle uses metal baffles made of plate material that has been slit and expanded.

It allows a longitudinal flow pattern, so that tube vibration will not occur (see Figure 4). EMbaffle bundle heat exchangers were used to replace conventional heat exchangers bundle in refineries. It has been reported that the EMbaffle technology generated 24 % higher thermal performance and lower pressure drop. Industrial applications showed that the tendency to fouling was almost twice as low for EMbaffle as with the segmental heat exchanger type. This leads to energy savings and reduction in CO2 emissions. In addition, 18 % fewer tubes were installed in the EMbaffle heat exchanger, offering a significant cost saving on equipment.

Industrial case study of EMbaffle heat exchanger in a complex refinery resulted in energy savings of 113kEuro per year, CO_2 reduction of 4 kt per year and optimum operation time without cleaning [3].

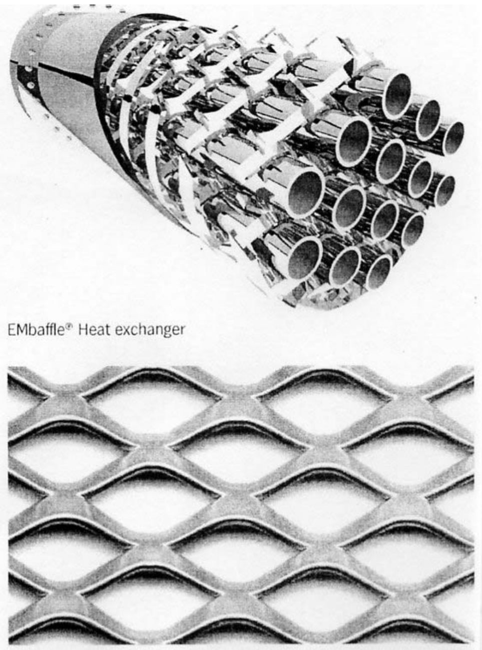


Figure 4: EMbaffle heat exchanger [3]

d) Twisted Tube Heat Exchangers

The twisted tube exchanger was developed originally to overcome the limitations inherent with conventional shell-and-tube technology. It consists of a bundle of uniquely formed tubes assembled in a bundle without the use of baffles**.** A wide range of tube materials can be used including carbon and stainless steel; Cr-Mo etc…

The twisted tubes are formed by a single step process producing tubes with an oval cross section and a superimposed twist.

With this technology, the shell-side flow experiences a swirling motion similar to the tube-side flow. This results in increased turbulence for the tube-side as well as shell-side flow. The twisted tubes promote turbulence and enhance the heat transfer coefficient (see Figure 5a). The twisted tube designs give 40 % higher heat transfer coefficients than the conventional single segmental baffle shell-and-tube exchanger for the same pressure drop (see Figure 5b). Applications of twisted tube exchangers in industry resulted in significant improvement in the performance and greater savings in energy [4].

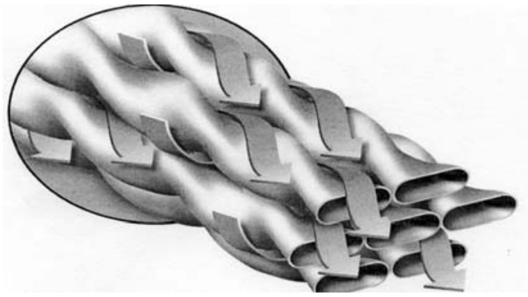
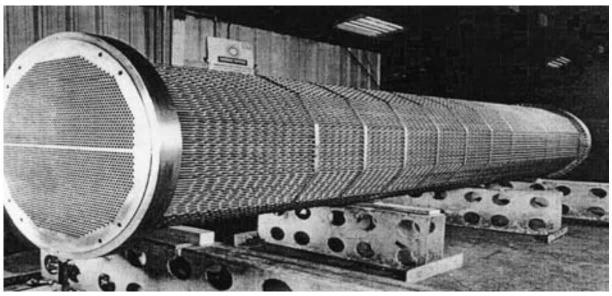


Figure 5a: Shell-side flow in twisted tube heat exchanger [4]



e) Corrugated tube exchangers

Corrugated-tube heat exchangers, designed for handling viscous and non-Newtonian liquids, are essentially double-pipe exchangers made from corrugated tubes. Several corrugated tubes geometries have been developed and used in several applications in industry (see Figure 6). Both shell-side and tube-side heat transfer surfaces are enhanced. These corrugated tube exchangers are suitable for duties requiring long and small diameter exchangers.

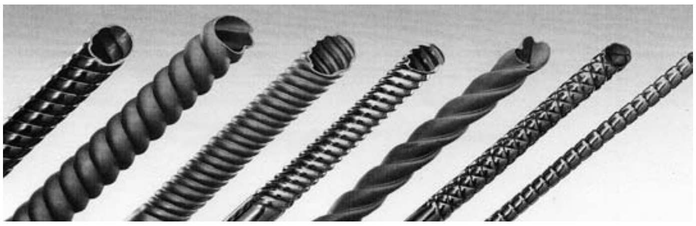


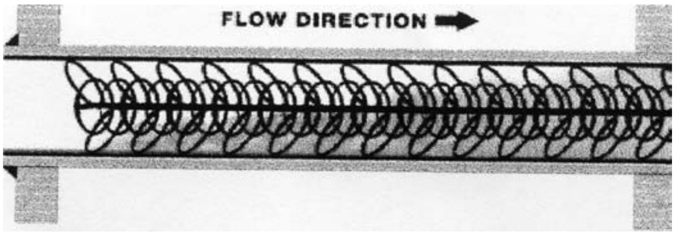
Figure 6: Corrugated tubes

4.2 Tube-side enhancement - Tube Inserts Heat Exchanger

In the case of shell-and-tube heat exchangers, several tube-side enhancement techniques have been developed such as twisted tape inserts, coiled wire inserts, mesh and brush inserts. Inserts are inserted into the tubes to promote turbulence (see Figure 7). Increases in the heat transfer film coefficient can be as high as five times. These devices are most effective with high viscosity fluids in laminar flow regime. Heat exchanger tube inserts have been used for heat transfer enhancement and fouling in petroleum refineries. Several applications of these exchangers for dirty hydrocarbon services in crude oil refining showed improved heat transfer performance and extended run times of the plant. The inserts tend to promote radial flow from the center to the wall and the fluid flow motion minimizes deposits on the tube wall.

Several applications of tube inserts in shell-and-tube heat exchangers in crude oil unit pre-heat trains have been reported in the literature [5]. Compare to conventional shell-and-tube exchangers, better performances for fouling mitigation and heat transfer enhancement where achieved with the enhanced exchanger. Significant energy savings and reduced maintenance cost have been achieved in all applications.

HiTran Matrix Elements Systems Technology, developed by Cal Gavin Limited, were used to enhance the tube-side heat transfer rate in combination with Helixchanger technology on the shell-side heat exchangers in a crude oil preheat exchangers unit. It has been reported that this enhancement resulted in a 400 % increase in overall heat transfer coefficient and reduced fouling in both sides of the exchanger [6].



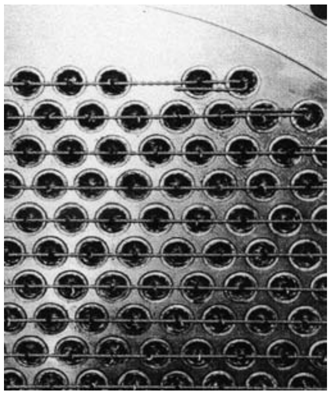


Figure 7: Tube Inserts inside tubes of shell-and-tube heat exchanger [6]

4.3 Compact heat exchangers technology

In recent years, plate-type heat exchangers have emerged as a viable alternative to shell-and-tube exchangers. They present several advantages mainly close approach and close temperature cross applications economically.

a) Gasketed Plate Heat Exchagers (GPHE)

The most common of the pate-type exchangers is the gasketed plate-and-frame heat exchangers (see Figure 8). GPHE consists of a series of channeled plates that are mounted on a frame and clamped together. Each plate is made with different materials (stainless steel, nickel, titanium etc.) and is formed with a series of corrugations (see Figure 9). The elastomer gasket plates are assembled in a pack, mounted on upper and lower guide rails, and compressed between two end frames by compression bolts. GPHE can be used in almost any application. In operations, the GPHE yields heat transfer rates three to five time greater than conventional shell-and-tube exchangers. The corrugated plates produce highly turbulent flow which keeps fouling to a minimum. The heat transfer area of GPHE can be modified after installation by adding or removing plates. GPHEs are limited to design pressure of 300 psig and design temperatures are function of the gasket material used.

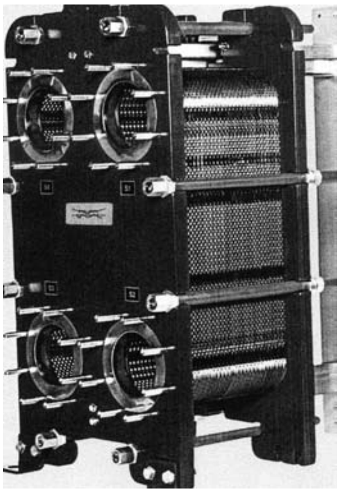


Figure 8: Gasketed plate heat exchanger [8]

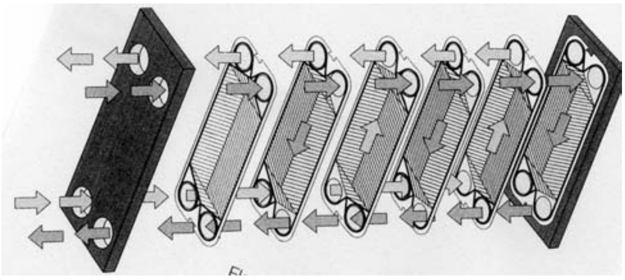


Figure 9: Flow circulation in GPHE [8]

b) Plate Fin Heat Exchangers (PFHE)

Brazed aluminum heat exchangers are manufactured as an all brazed and welded pressure vessel with no mechanical join. The core matrix is produced by vacuum brazing; that is joining the fins, bars and parting sheets (see Figure 10). A wide range of corrugated fin patterns (plain, perforated, herringbone and serrated) accommodate different thermal and hydraulic process requirement. These compact heat exchangers can use up to 12 streams in a single block and unlimited range of flow options (counter flow, cross flow, parallel flow and multi-pass) (see Figure 11).

Due to their high surface area compactness, PFHE possess superior heat transfer capabilities and can be cost effective for non-corrosive gases and liquids as compared with traditional shell-and-tube heat exchangers.

PFHE has been mainly used in cryogenic applications where small approach temperatures are important. Important areas of application are natural gas processing, LNG production and petrochemical processing.

While PFHE should be used with relatively clean process streams, the advantage of close temperature approach, compactness, low weight and a unique ability to exchange heat with multiple streams make them ideal alternative to shell-and-tube exchangers for numerous processing applications such as gas production, hydrogen and helium liquefaction.

The brazed-plate design is typically rated at pressures up to 450 psig and temperatures up to 500 °F.

The major limitation of PFHE is the size of the plates that can be brazed. In addition, these heat exchangers should not be used in the event of fouling [7].

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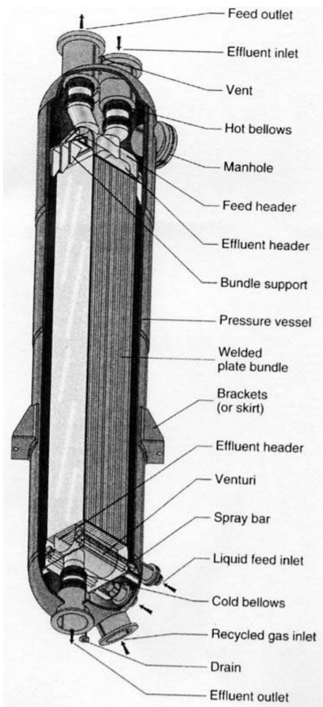

Figure 12: Packinox Heat Exchanger [8]

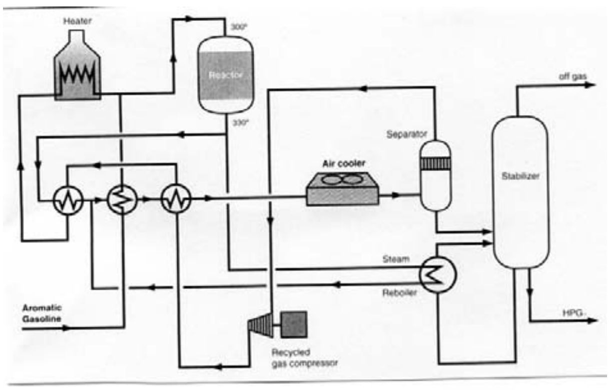

Figure 13a: Catalytic reforming preheat train with twelve shell-and-tube heat exchangers [8]

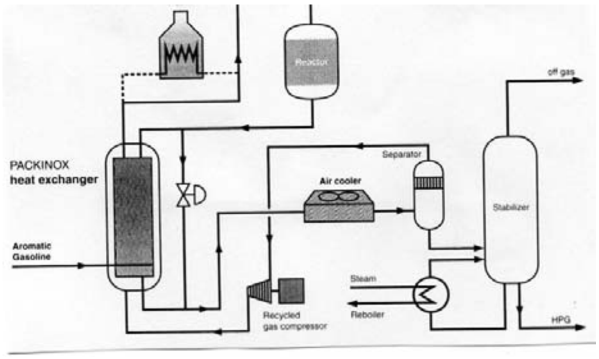

Figure 13b: Catalytic reforming preheat train with one packinox heat exchanger [8]

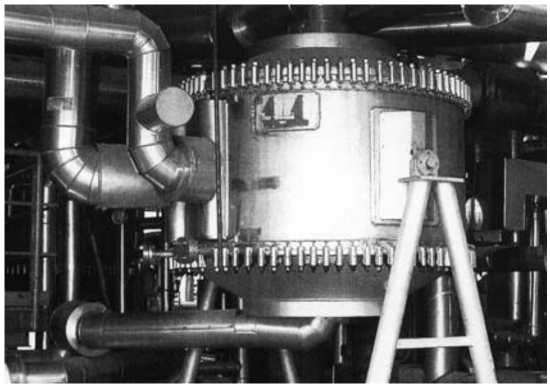

Figure 14: Spiral heat exchanger [8]

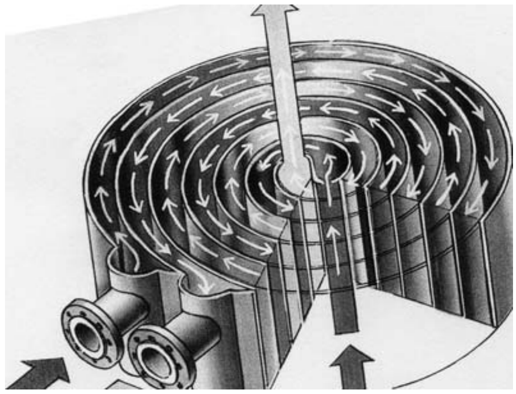

Figure 15: Flow circulation in spiral heat exchanger [8]

d) Spiral heat exchangers (SHE)

A spiral heat exchanger is a circular heat exchanger with two concentric spiral channels, one for each fluid (see Figure 14). The fully counter current flow in the channels provide high heat transfer (see Figure 15). This results in maximum energy recovery. The spiral design causes a scrubbing effect that removes fouling deposits. Because of this self cleaning effect, SHEs are particularly useful with fluids that cause fouling. Due to severe fouling problems in a preheat train visbreaking feed/bottom interchangers in an European refinery, eight spiral heat exchangers were used to replace conventional shell-and-tube heat exchangers. It has been reported that this replacement resulted in improved heat recovery, reduced maintenance costs and no capacity loss [9].

5. CONCLUSIONS

Significant improvements in the performance of an existing heat exchanger can be achieved by replacing conventional shell-and-tube exchangers with shell-side and tube-side enhancements or compact heat exchangers. Enhancement in shell-and-tube heat exchangers can be performed by using recent advances and design of heat exchangers technology.

In new design or revamping of heat exchangers, it is necessary to select the most suitable technology in order to obtain high performance and overcome the limitations inherent to conventional heat exchangers. These range from efficient forms of heat exchangers to process integration and process intensification.

emissions).

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Oil and gas industries can realize significant savings by using the latest heat exchanger technology as a means to lowering costs while expanding plant capacity.

The increase in energy price and the environmental constraints on CO_2 emissions are behind the interest of petroleum and gas companies to look for new heat exchangers technologies for a more efficient energy recovery and a sustainable development.

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