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EUROPEAN ROADMAP OF PROCESS INTENSIFICATION

- TECHNOLOGY REPORT -

TECHNOLOGY: ADVANCED SHELL & TUBE TYPE HEAT EXCHANGERS

TECHNOLOGY CODE: 1.1.2

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Table of contents

1. Technology
- 1.1.1-5 Description of technology / working principle
- 1.2.1-5 Types and "versions"
- 1.3 Potency for Process Intensification: possible benefits
- 1.4 Stage of development

2. Applications
- 2.1 Existing technology (currently used)
- 2.2 Known commercial applications
- 2.3 Known demonstration projects
- 2.4 Potential applications discussed in literature

3. What are the development and application issues?
- 3.1 Technology development issues
- 3.2 Challenges in developing processes based on the technology

4. Where can information be found?
- 4.1 Key publications
- 4.2 Relevant patents and patent holders
- 4.3 Institutes/companies working on the technology

5. Stakeholders
- 5.1 Suppliers/developers
- 5.2 End-users

6. Expert's brief final judgment on the technology

1. Technology

1.1.1 Description of technology / working principle

(Feel free to modify/extend the short technology description below)

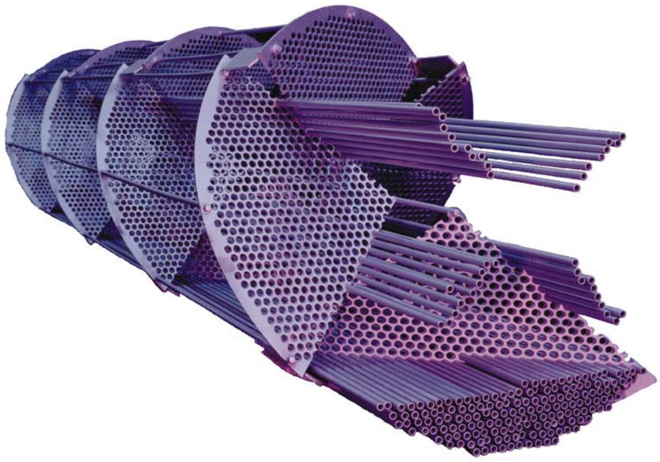
In a HELIXCHANGER® Heat Exchanger, the conventional segmental baffle plates are replaced by quadrant shaped baffle plates acting as guide vanes and are positioned at a unique angle to the tube axis creating a uniform velocity helical flow through the tube bundle. Near plug flow conditions are achieved with little back-flow and eddies, often responsible for fouling and corrosion. This advanced shell & tube heat exchanger with helical baffles provides significant advantages over the conventional shell & tube heat exchanger, which include lower total life cycle costs, fouling mitigation, reduction in size and surface area, extended run-length and effectively elimination of flow-induced vibrations. So far more than 2000 units are in operation.

1.2.1 Types and “versions”

(Describe the most important forms/versions of technology under consideration, including their characteristic features, differences and similarities)

HELIXCHANGER® Heat Exchanger can be combined with other Technologies like tube inserts: HELITURB® and low-fin tube: HELIFIN® . Also single large vertical positioned exchanger so called HELITOWER®. This is a synonym of “TEXAS TOWER” used in Feed Effluent heat exchange in CCR, HDS and platformers. Combination with high pressure closure heat exchanger is called HELILOCK®
Alll types are marketted by ABB Lummus Heat Transfer BV who are recently sold to Chicago Bridge & Iron. Very recently the first applications of Helireactor have been put in service.

ILLUSTRATIONS:



1.1.2 Description of technology / working principle

(Feel free to modify/extend the short technology description below)

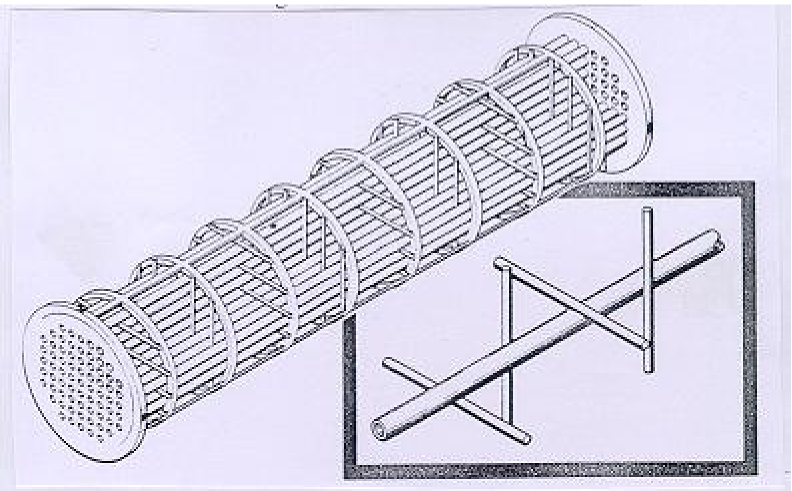
In a Rod Baffle shell & tube type the conventional baffles are replaced by rods. The rods are welded to rings which are positioned every 300-500 mm. and support the tube in various directions. The shellside flow is longitudinal flow and once the rod is touching a tube the boundary layer is being disturbed and does have positive effect on the outer film heat transfer coefficient. This technology is being used in services to avoid high shellside pressure drop and/or vibration.

1.2.2 Types and “versions”

(Describe the most important forms/versions of technology under consideration, including their characteristic features, differences and similarities)

Also this technology can be combined with other technologies like low-fin tubes and tube inserts. Large vertical units have been installed. The first time it was introduced by Phillips Petroleum. So far approximately 2000 units are installed globally.

ILLUSTRATION:



1.1.3 Description of technology / working principle

(Feel free to modify/extend the short technology description below)

In an EM Baffle the conventional baffles are being replaced by slitted sheets of expanded metal where the tubes protrude through the holes formed after the expanding procedure.

The open structure results in a low hydraulic resistance and enhanced heat transfer.

The shellside flow is longitudinal flow and once the fragment slit is touching a tube the boundary layer is being disturbed and does have positive effect on the outer film heat transfer coefficient. This technology is being used in services to avoid high shellside pressure drop and/or vibration.

1.2.3 Types and "versions"

(Describe the most important forms/versions of technology under consideration, including their characteristic features, differences and similarities)

This is a Shell Global Solution invention, marketed by EM Baffle BV.
So far approximately 15 units are in operation mainly Shell owned plants.
Also this technology can be combined with other technologies like low-fin tubes and tube inserts. In order to create sufficient high shell side flow, longitudinal baffle plates are being installed. Up to now units are provide with 2 long baffle plates only so called 3 shell-pass design. More long baffle plates will have large impact on the mechanical design and more difficult to fabricate.

ILLUSTRATION:

1.1.4 Description of technology / working principle

(Feel free to modify/extend the short technology description below)

Low-fin tube

Cold forming technique using series of disc's pressed on a plain tube will result in a structure of low fin formation (see Figure A). The main objective is to have 2.5 times more external surface area.

Twisted Tube

Proprietary forming technique will result in helix shaped tubes (see Figure B) arranged in a triangular pattern. Each tube is supported by the next tube and is self supporting without using baffles. The outer end of the tubes is round in order to make use of the common standard tube-tubesheet joint.

1.2.4 Types and "versions"

(Describe the most important forms/versions of technology under consideration, including their characteristic features, differences and similarities)

Low Fin tubing is made by different manufactures using their own deformation techniques. After penetration the market with only outside finning, there is a trend for further enhance the tube with by internal fin structure.

Twisted Tube is marketed by Koch Heat Transfer Group. A low fin tube version has been developed to create more external area leading to more compact design.

ILLUSTRATIONS:

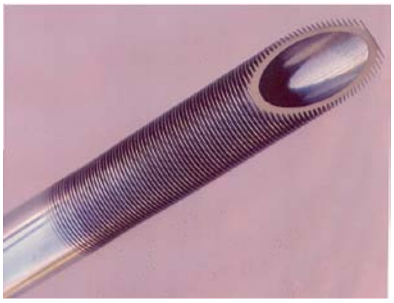


FIG. A

FIG.B

1.1.5 Description of technology / working principle

(Feel free to modify/extend the short technology description below)

Tube insert
Matrix wired elements (Fig.A) are used inside tubes of heat exchangers (Shell & Tube and Aircooled type) The wire loop is able to break the laminar boundary layer at the tubewall so turbulence flow regime is achieved at lower Reynolds numbers.
The wire looping can be adjusted to fit client needs. Expected higher pressure drop to gain higher heat transfer. Smart insert design can result in equal pressure drop as in bare tube design. Many applications in retro-fitting have resulted that also grass-root plants are being designed from scratch including these insert.
Inserts are being used as fouling mitigation devices.

1.2.5 Types and "versions"

(Describe the most important forms/versions of technology under consideration, including their characteristic features, differences and similarities)

The intensity of the wire loops can be adjusted to create fit for purpose design.
Other versions like single spring wire elements have been developed (Fig.B)
By fluid flow the spring wire is moving in various directions and is able to mechanical disturb the boundary or fouling layer.

ILLUSTRATIONS:

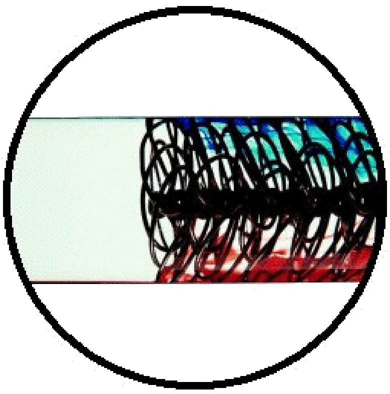


FIG. A

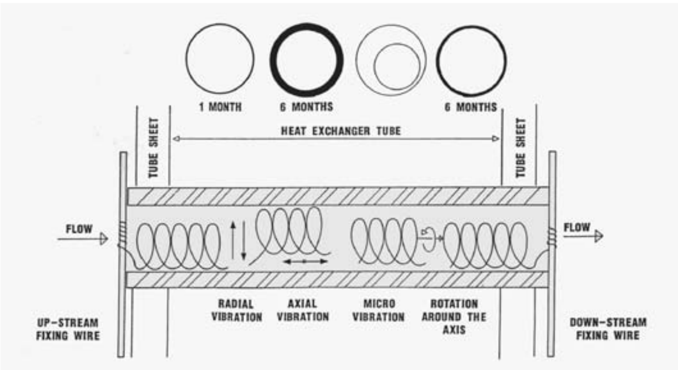


FIG. B

1.3 Potency for Process Intensification: possible benefits

(In Table 1 describe the most important documented and expected benefits offered by the technology under consideration, focusing primarily on energy; CO_2 emission and costs, providing quantitative data, wherever possible. Add other benefits, if needed).

All mentioned Technologies can be classified as fouling mitigation devices.
Fouling in exchangers cost 0.25% of World BNP per year.
Only in The Netherlands this value represents € 1.000.000.000,= per annum.

Table 1: Documented and expected benefits resulting from technology application

Benefit	Magnitude	Remarks
Energy Savings	50%	EM Baffle and Helixchanger do claim energy savings as mentioned in SenterNOVEM's EIA Regulation Energielijst. Energy-saving is 0.025-0.060 PJ/year for a 10 MW Shell & Tube heat exchanger. OPEX saving € 50.000,= up to € 125.000,= per year is possible.
Less CO2 emission	100%	The technologies individually can generate substantial CO2 reduction, but combinations of inside and outside fouling mitigation technologies have enormous potential in retrofit and grass root plants.
Cost Saving	20 to 200%	Number of shells can be reduced by factor of two. This type of saving is important where weight and plotspace are key drivers. There are proven examples in Off-shore and FPSO applications.
Safety		Baffle geometry is mechanical a non pressure part acting as support only. Low fin tube is recognized by ASME code to have extra mechanical strength as the ribs act as reinforcing.
Fouling		Presented technologies are by industry recognized fouling mitigation.
Maintenance		The baffle geometries will lead to less fouling by a factor of 3, and therefore cleaning cycles will be extended. Less shutdowns are the net result.

1.4 Stage of development

Except for EM Baffle all other Technologies mentioned are fully matured.

2. Applications

2.1 Existing technology (currently used)

(Describe technology (-ies) that are conventionally used to perform the same or similar operations as the PI-technology under consideration)

Conventional Baffled heat exchangers are commonly used but suffer from fouling, higher pressure drop and tube vibration.

2.2 Known commercial applications

(Is the technology broadly applied on commercial scale? In which process industry sectors is the technology most often applied: large volume chemicals – specialty chemicals & pharma – consumer products – ingredients based on agro feedstocks? What is the estimated number of existing applications? In Table 2 provide the most prominent examples of realized applications and provide their short characteristics)

Table 2. Industrial-scale applications of the Technology (existing and under realization)

Sector	Company - Process/Product name/type	Short characteristic of application	Production capacity /Plant size	Year of application	Reported effects
Chemical	Many End Users				•
Petro	Many End Users				
Pharma	Some End Users				
Food	Some End Users				

2.3 Known demonstration projects

(Are there any demonstration projects known related to the technology under consideration? In which process industry sectors are those projects carried out: large volume chemicals – specialty chemicals & pharma – consumer products – ingredients based on agro feedstocks? In Table 3 provide the short characteristics of those projects.)

Rod Type and Helical Baffle type Shell Tube Heat exchangers are matured technologies so demonstration projects are covered by numerous life plant examples.

EM Baffle Technology is rather new and has limited amount of references.

Low Fin Tube Technology is matured and are covered by numerous life plant applications.

Insert Technologies are matured and have many references.

Table 3. Demonstration projects related to the technology (existing and under realization)

Sector	Who is carrying out the project	Short characteristic of application investigated, including product name/type	Aimed year of application	Reported effects
EM Baffle in CDU	Shell Netherlands Refinery	CDU, fouling	2005	• classified SenterNOVEM report
Helireactor	Dupont, Spain	Phosgene Reactor	2007	

2.4 Potential applications discussed in literature

(Provide a short review, including, wherever possible, the types/examples of products that can be manufactured with this technology)

The literature concerning the potential applications of EM, helical baffle and Rod type type heat exchangers is very rich. There are many Petro – Chemical and Utility examples. Low-fin outside finned there are many applications. Combination in and outside finned tubes are starting to find their way in specific processes.
Tube inserts, acting as static mixer, find their way in vent condensers, vacuum condensers, reflux condensers and condensation wide boiling mixtures.
First reactors applications are reported. Limited literature information yet.

3. What are the development and application issues?

3.1 Technology development issues

(In Table 4 list and characterize the essential development issues, both technical and non-technical, of the technology under consideration. Pay also attention to "boundary" issues, such as instrumentation and control equipment, models, etc.) Also, provide your opinion on how and by whom these issues should be addressed)

Table 4. Technology development issues

Issue	**Description**	**How and by whom should be addressed?**
EM Baffle	Helical Geometries	Shell Global Solutions
Helixchanger	F-type	Temperature cross

3.2 Challenges in developing processes based on the technology

(In Table 5 list and characterize the essential challenges, both technical and non-technical, in developing commercial processes based on the technology under consideration. Also, provide your opinion on how and by whom these challenges should be addressed)

Table 5. Challenges in developing processes based on the technology

Challenge	**Description**	**How and by whom should the challenge be addressed?**

4. Where can information be found?

4.1 Key publications

(Provide the list of key publications in Table 6)

Table 6. Key publications on the technology

Publication	Publication type (research paper/review/book/ report)	Remarks
Lutcha J., Nemcanski J. “Performance Improvement of Tubular Heat Exchangers by Helical Baffles”, Trans.IChemE, Vol68, Part A pp 263-270, 1990	Paper	
Kral D., Stehlik P., van der Ploeg H.J., Master B., “Helical Baffles in Shell and Tube Heat Exchangers Part I: Experimental Verification. Heat Transfer Engineering, Vol.17, Nov.1996	Paper	
Andrews M., Master B., “3-D modeling of the ABB Lummus Heat Transfer Helixchanger using CFD”, Int.Conf. on Compact Heat Exchangers and Enhancement Technology for the Process Industry, Banff Canada July 19-23, 1999	Paper	
Master B., Chunangad K., Boxma B., Polley G, Tolba M., “Reduced Total Life Cycle Cost using Helixchanger Heat Exchanger and Enhancement Technology for the process industries”, Davos, Switzerland July 2001.	Paper	
O’Donnell Jr. J., Master B., “Design Enhancements Boost Heat Exchanger Performance”, Hydrocarbon Asia, AP energy Publications Pty. Ltd. UK Sept.Oct. 2003	Paper	

4.2 Relevant patents and patent holders

(Provide the list of relevant patents in Table 7. Under “remarks” provide, where applicable, the names/types of products targeted by the given patent.)

Table 7. Relevant patents

Patent	Patent holder	Remarks, including names/types of products targeted by the patent
Czech and USA	ABB	Helixchanger
The Netherlands and USA	Shell Global Solutions	EM Baffle
UK	Cal Gavin	Hi-Tran
USA, Germany	HPT, Wolverine,Wieland	Low Fin

4.3 Institutes/companies working on the technology

(Provide the list of most important research centers and companies in Table 8)

Table 8. Institutes and companies working on the technology

Institute/Company	Country	Remarks
HTRI	USA	EM Baffle
HTRI, ABB/CBI, KHT	USA	Helixchanger, HeliBaffle
HTRI, Cal Gavin, Petroval	USA, UK,France	hiTran, Turbotal
HTRI, HPT, Wolverine,Wieland	USA,Germany	Low Fin Tube
HTRI, Koch Heat Transfer Group	Italy/USA	Twisted Tube

5. Stakeholders

5.1 Suppliers and developers

(Provide the list of key suppliers/developers in Table 9)

Table 9. Supplier and developers

Institute/Company	Country	Remarks
EM Baffle BV	The Netherlands	EM Baffle
ABB/CBI, Koch Heat Transfer	USA	Helixchanger, HeliBaffle
Cal Gavin, Petroval	UK,France	hiTran, Turbotal
HPT, Wolverine,Wieland	USA,Germany	Low Fin Tube
Koch Heat Transfer Group	Italy/USA	Twisted Tube

5.2 End users

(Describe the existing and potential end-users, other than those already listed in Table 2)

Oil Exploration and Production; Gas production, transmission and treatment; Oil Refining; Petrochemical and downstream processing; Organic and Inorganic Chemicals; Plastic, polymers and resins; Specialty and fine chemicals; Fertilisers and agro-chemicals; Food processing and pharmaceuticals; Refrigiration and cryogenics; Power generation and distribution.

6. Expert's brief final judgment on the technology

(maximum 5 sentences)

There is a trend end users are getting more confident in using advanced Shell & Tube Technologies. Through learning curve in retrofiiting application slowly but steadily these Technologies are being specified and used in grass root plants.