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AN EXPERIMENTAL COMPARISON OF BRAZED TYPE PLATE HEAT EXCHANGERS BASED ON LIFETIME REQUIREMENTS OF A COMBI BOILER INDUSTRY

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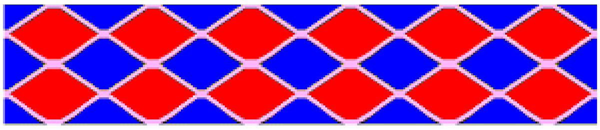
ABSTRACT

Brazed type Plate Heat Exchangers (BPHEs) are the most-preferred components for sanitary water heating purpose in combi-boilers. Asymmetric type BPHEs are recently the most preferred PHE types in combi boilers due to their enhanced heat transfer. Bosch has developed its own asymmetric BPHE considering increase in both heat transfer and lifetime compared to known asymmetric BPHE. This study compares the effect of channel geometries of two asymmetric type BPHEs on the heat transfer and the scale formation during operation.

INTRODUCTION

The field failure rates of the combi-boilers suggest that the fouling and the scale formation through the sanitary water channels of BPHE have the major effect on component lifetime. One of the conventional methods to reduce the fouling and the scale formation is to use additives. This method is applied in the central heating circuit of the combi-boilers; however, not applicable for the sanitary water circuit. Periodical cleaning is another method, which is not an effective and economical solution against the scale formation in BPHEs. The disassembly of BPHEs is not possible; therefore the effectiveness of the cleaning process is questionable since it depends on the service conditions such as time, chemical type, etc. Due to the mentioned constraints, the channel geometry is critical on BPHE lifetime in the combi-boilers.

Hot and cold water channels' cross-sections of two different BPHE types are shown in Fig.1. Both hot and cold channel volumes are equal in the symmetric BPHE. In the known asymmetric BPHE, cold water channel is narrower than hot water channel. Reduction in the cold water volume increases the pressure drop and therefore the heat transfer compared to the symmetric BPHE.



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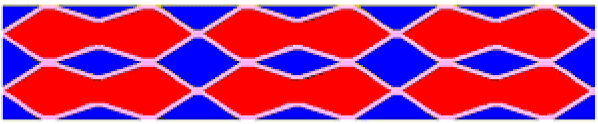

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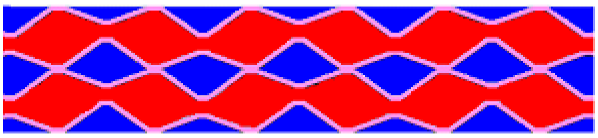
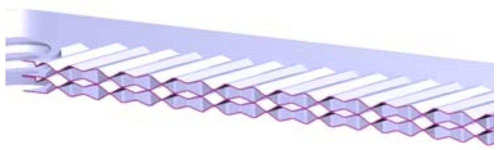


(c)

Fig. 1 Cross-sectional view of heating water (in red) and sanitary water (in blue) in (a) symmetric, (b) known asymmetric and (c) Bosch asymmetric BPHEs

Bosch asymmetric BPHE has improved heat transfer compared to known asymmetric BPHE due to optimized fishbone geometry. Fig.2 shows the irregular form heights on fishbone geometry of Bosch asymmetric BPHE, which is regularly distributed on that of known asymmetric BPHE.



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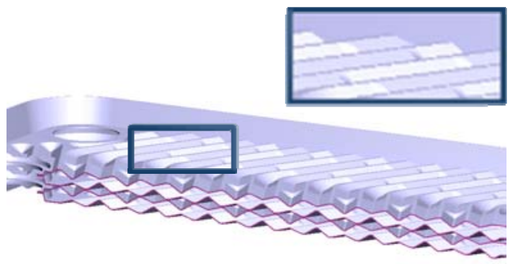

(b)

Fig. 2 Fishbone geometry of (a) known asymmetric and (b) Bosch asymmetric BPHEs

Computational Fluid Dynamics Results

Heat transfer and pressure drops of the known and Bosch asymmetric BPHEs were compared by numerical simulation using ANSYS Fluent software.

Table 1 shows the increase in pressure drop through the sanitary water channel of Bosch asymmetric BPHE.

Table 1. Pressure Drop CFD results

PHE Type	Pressure Drop (Pa)	
	Sanitary Water Channel	Heating Water Channel
Known asym. BPHE	2848	6063
Bosch asym. BPHE	3556	5289

Bosch asymmetric BPHE achieves higher pressure drop through the sanitary water channel while decreasing that through the heating water channel. This is an important improvement for combi-boiler hydraulics since heating water is pressurized by a pump. Therefore there is no need to increase the pump head and to bring additional cost. In direct contradiction, increase in pressure drop through the sanitary water channel is not binding and advantageous for the heat transfer. As shown in Table 2, 8% increase in heat transfer was calculated in Bosch asymmetric BPHE compared to known asymmetric BPHE.

Experimental Results

The known and Bosch asymmetric BPHEs are tested under the same combi-boiler working conditions and using same sanitary water composition as shown in Table 3 to evaluate their lifetime performances based on scale formation.

In Figure 3, Central Heating (CH) water return temp to BPHE heating water channels were plotted during the test duration shown in months. CH return temperature has a limit in each combi-boiler due to safety reason. The limit in the test combi boiler was 95°C. The CH return temperature of known asymmetric BPHE reached the limit temperature earlier.

Table 2. Heat Transfer comparison of the known and Bosch BPHEs

	Known Asymmetric BPHE			Bosch Asymmetric BPHE		
	Heat Flux (W/m^2)	Area (m^2)	Q (W)	Heat Flux (W/m^2)	Area (m^2)	Q (W)
cold water volume top surface	107100	0.01219	1277	105700	0.01326	1402
cold water volume bottom surface	104800	0.01216	1301	111495	0.01244	1387
TOTAL			2578			2789

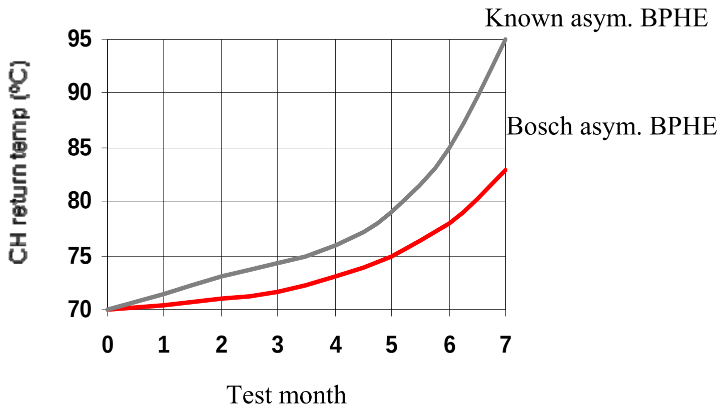

Figure 3. Central Heating (CH) water return temperature vs test month

Table 3. Initial operating conditions

Initial Operating Conditions		
	Bosch asym. BPHE	Known asym. BPHE
Appliance nominal heat input (kW)	24	24
Flow Rate(l/min)	7,0	7,0
$T_{Domestic\ hot\ water\text{-}\ out}$ (°C)	59	59
BPHE Weight (gr) - before operating	960	910
BPHE Weight (gr) - after operating	1010	1030

DISCUSSION

The increase in the pressure drop through the sanitary water channel shows the turbulence therefore mixing is higher in Bosch asymmetric BPHE. The high degree of turbulence keeps particles in suspension which otherwise may settle onto the heat transfer surfaces (Bansal et al., 2000). Figure 3 shows the positive effect of reduced scale formation rate in Bosch asymmetric BPHE on combi-boiler lifetime increased approximately by 20%.

In order to understand the effect of significant parameters on the scaling rate of BPHE; an experimental setup has been designed and built. The most critical set of parameters as shown in Table 4 below have been selected based on the requirements of EN 13203-Part 2 standard, European drinking water directive, world health organization guidelines and the field experience. The impact of each parameter on the scale formation rate - by relating the scale formation rate to the drop in the total heat exchanger effectiveness - will be examined for three different BPHE types to be able to predict and declare the life time of these BPHEs in terms of scaling behaviour. In addition, the experimental data will be the basis of a general reduced-order theoretical model to be developed to predict and prevent the reduction in lifetime.

Table 4. Operating conditions

Experimental Inputs				
BPHE Type	T-CH_{in} (°C)	$\dot{m}_{DHW}$ (l/min)	Water pH	Water hardness (mg CaCO3 /lt)
Symmetric	85	16	9,5	300
Known asymmetric	72,5	9,5	8	175
Bosch asymmetric	60	3	6,5	50

CONCLUSIONS

1. The Bosch asymmetric BPHE sanitary water channels have higher pressure drop therefore higher turbulence rate compared to known asymmetric BPHE.
2. Due to increased turbulence rate, the lifetime of the combi-boiler has been increased approx. 20% with Bosch asymmetric BPHE.
3. The results of the experimental and theoretical study mentioned above will help us to design novel BPHEs for longer lifetime in terms of scaling and to adjust system parameters to extend the lifetime of already used BPHE types in heating appliances.

REFERENCES

Bansal, B., Müller-Steinhagen, H., and Chen, X.D., 2000, Performance of plate heat exchangers during calcium sulphate fouling, *Chemical Engineering and Processing*, Vol. 39, pp. 507-5019