ARMFIELD HT31 TUBULAR HEAT EXCHANGER IN THE EDUCATION

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Abstract

At numerous areas tubular heat exchangers were replaced by plate heat exchangers, because of their smaller place demand and better heat transfer. But easier structure, easier cleaning and new technical solutions turned the attention once again to tubular heat exchangers. They are widely used in food industry, in chemical industry, in pool technology and in building engineering.

At the Institute of Process Engineering (Szent István University, Faculty of Mechanical Engineering) the tuition of heat exchangers (their structure and sizing) is important. Till now at Szent István University the tuition of heat exchangers was about teaching theoretical knowledge, because there was no appropriate tooling. During the last year in the Knowledge Transfer Centre Project the university purchased an Armfield HT30XC heat exchanger and different heat exchanger accessories. At first, we made measures on the HT31 tubular heat exchanger with which we defined the operating interval of the equipment. At different adjustments we progressively changed the mass flow and temperature of hot and cold water. The collected data base can be used for teaching of heat exchanger processes. To show the processes we made diagrams. With these diagrams we help students to understand the steps of sizing and operating of heat exchangers.

With the collected data base, measurement documentation and diagrams the tuition of heat exchangers is complete and the practical teaching of students can be done on a higher level.

Keywords

heat exchanger, tubular heat exchanger, Armfield

Introduction

The role of heat exchangers is very important in practice. Extending of their application and modeling is needed in industry. Modeling of heat exchanger systems is a great responsibility, because the incidental failures occur increasingly. Our Armfiled HT31 tubular heat exchanger is applicable for the modeling of heat technical problems. Now, after theoretical studies there is a available equipment for tuition at Szent István University. At the Institute of Process Engineering (Szent István University, Faculty of Mechanical Engineering) the tuition of heat exchangers (their structure and sizing) is important.

We gradually changed cold and hot water mass flows and hot water temperature in our study. The set up data base is a good tool to demonstrate the heat transfer processes in heat exchangers.

Description of armfield ht30xc heat exchanger unit

In this experiment we used an Armfield HT30XC heat exchanger unit with HT31 Tubular Heat Exchanger. The Armfield range of small scale heat exchangers comprises several units which represent the common types of heat exchangers found in industry. They demonstrate different techniques for indirect transfer of heat from one fluid stream to another. Their small size produces a fast system response to changes in variables such as water flow rate and temperature, so that training exercises can be carried out in a relatively short space of time.

The interchangeable heat exchangers are individually mounted on a service unit (HT30XC) which provides the required services and sensor output displays.

The units can be quickly changed without the need for tools, and the service unit also allows students to evaluate experimental heat exchangers of their own construction. Once a heat exchanger has been installed on the service unit and the unit is switched on, the entire assembly can be operated remotely from a computer. The supplied Armfield control software also includes a full set of training exercises and allows data logging and display of results in tabular and graphical format.

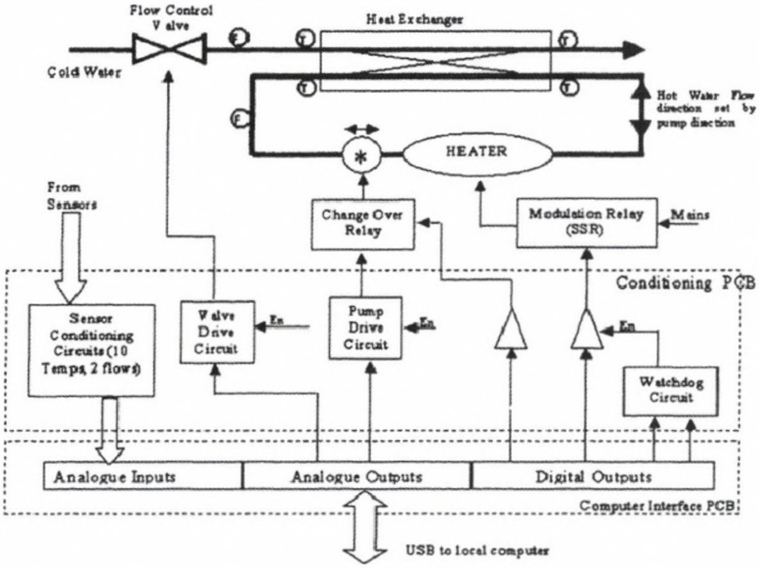


Figure 1. Simplified Block Schematic Diagram of the HT30XC Service Unit (Rubaiyat Amin Khan, 2000)

On Fig.1 the simplified block diagram of the Armfield HT30XC heat exchanger unit can be seen. The cold water circle, hot water circle and the measurement points (T-temperature measurement, F-mass flow measurement). The territory marked with broken lines traces the digital inputs and outputs.

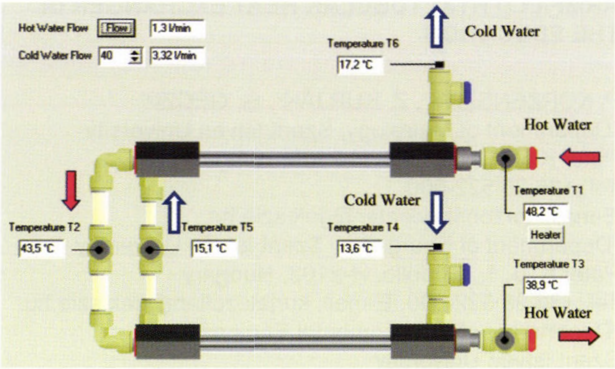
Cold water flow (the process flow) for the heat exchanger is derived from the local mains water supply, with the equipment protected by a pressure regulator and integral filter and the flow controlled by a proportioning solenoid valve. Flow meters measure the hot and cold flow rates, and thermocouple sensors measure the temperature at key points throughout the heat exchanger. Once a heat exchanger is connected, the unit can be entirely operated via a computer and all sensor outputs can be logged. The hot water flow rate can be controlled from the computer software by varying the rotational speed of the re-circulation pump. Again this can be set from 0% to 100%, with the actual flow rate being measured by a flow meter and displayed in L/min on the computer screen.

The tubular heat exchanger is the simplest form of heat exchanger and consists of two concentric (coaxial) tubes carrying the hot and cold fluids. Heat is transferred to/from one fluid in the inner tube from/to the other fluid in the outer annulus via the metal wall which separates the two fluids. In the HT31 version two separate concentric tubes are arranged in series in the form of a U to reduce the overall length and allow the temperature mid way along both fluid streams to be measured. This arrangement minimises heat loss from the exchanger without the need for additional insulation and allows the construction of the exchanger to be viewed.

Figure 2. Armfield HT30XC heat exchanger unit (www.armfield.co.uk/ht30xc)

The six - type K - thermocouple temperature sensors are labelled T_1 to T_6 for identification and each lead is terminated with a miniature thermocouple plug for connection to the appropriate socket of the console on the service unit. Thermocouples are installed at the following locations (when operated counter current):

T_1 – Hot water inlet [°C]
T_2 – Hot water mid-position [°C]
T_3 – Hot water outlet [°C]
F_{hot} – Hot water flow rate [l/min]
T_4 – Cold water inlet [°C]
T_5 – Cold water mid-position [°C]
T_6 – Cold water outlet [°C]
F_{cold} – Cold water flow rate [l/min]



Hot Water Flow 1,3 l/min
Cold Water Flow 40 3,32 l/min
Temperature T6 17,2 °C
Temperature T1 48,2 °C
Temperature T2 43,5 °C
Temperature T5 15,1 °C
Temperature T4 13,6 °C
Temperature T3 38,9 °C

Figure 3. Armfield HT31 Tubular Heat Exchanger (www.armfield.co.uk/ht30xc)

Technical details of HT31 Tubular Heat Exchanger are as follows:

- Each inner tube is constructed from stainless steel tube, 9.5mm outlet diameter, 0.6mm wall thickness.
- Each outer tube is constructed from clear acrylic tube, 12mm inlet diameter, 3.0 mm wall thickness.
- Each heat transfer section is 330 mm long giving a combined heat transfer area of approximately 20000 mm^2.

Measurement setup

Two modes are available for controlling the hot water temperature, a manual control mode to provide constant heater power and an auto temperature control mode. Both modes are accessed via the software. In this experiment we used the auto control mode. In auto mode, the power to the heaters is modulated in accordance with a PID algorithm to achieve a stable temperature at one of the sensors (usually the hot water inlet to the heat exchanger).

During the measurements we modified the hot water temperature, hot and cold water flowrate, but only one of the main parameters was changed at the same time.

Each measurement series was repeated four times, the results were averaged and temperature curves were created.

We made our measurements with 6 different hot water ($Q_{hotwater}$) and 6 different cold water mass flow ($Q_{coldwater}$) values. We parallel modified inlet hot water values (T_1=30, 40, 50 ,60°C-ra). We modified only one parameter at once. With a constant cold water temperature (T_4) we adjusted the needed hot water temperature (T_1). We checked at given hot water mass flow (Q_{hot}) the temperature increase of the hot water side ($D_{Thot}=T_1-T_3$) with the increase of cold water mass flow (Q_{cold}).

On Fig.4 the results of five adjustments can be seen. With the increase of cold water mass flow the temperature difference of hot water inlet and outlet side increased.

Conclusions

In the following we introduce the application limits of the Armfield HT31 Tubular Heat Exchanger equipment.

We show at constant inlet hot water temperature (T_1=50°C) and at constant inlet cold water (T_4=12°C) the measured temperature at adjusted hot water and cold water mass flows (T_3 - hot water out, T_6 – cold water out).

With the increasing of hot water mass flow the outlet hot water temperature caused less temperature difference (compared to constant inlet 50°C hot water temperature).

With the increasing of cold water mass flow, and at constant hot water mass flow the outlet cold water temperature is decreasing, so heat transfer is decreasing as well. Due to the effect of great cold water and hot water mass flow the values cannot be interpret in the grey parts of the table.

The Armfield HT31 Tubular Heat Exchanger is applicable for measurements on the adjusted 50°C inlet hot water temperature and 12°C cold water temperature at 4.4l/min mass flow.

At increased 9.9 l/min mass flows the equipment in not applicable for modeling.

Acknowledgements

This work was financially supported by TÁMOP 4.2.1.B-11/2/KMR-2011-0003 project.

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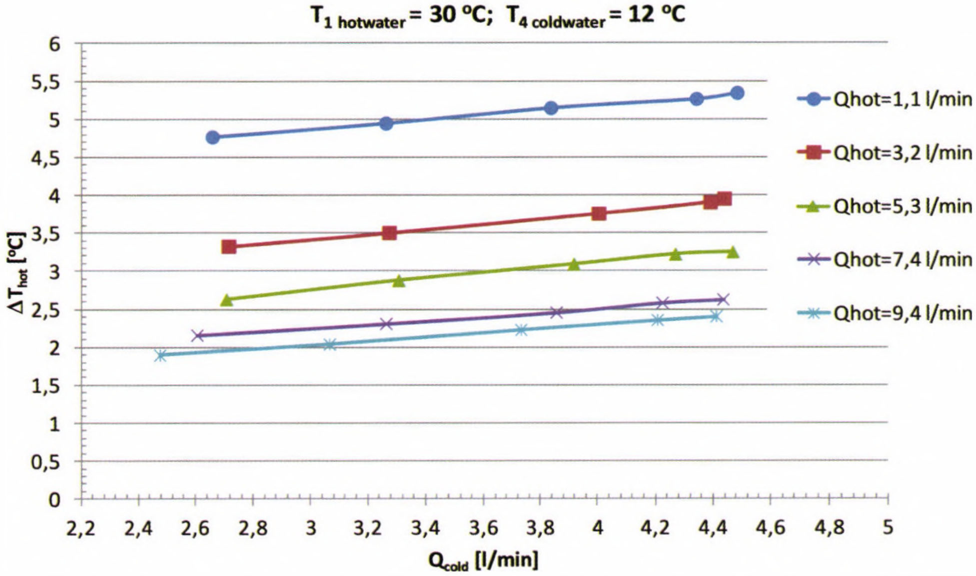
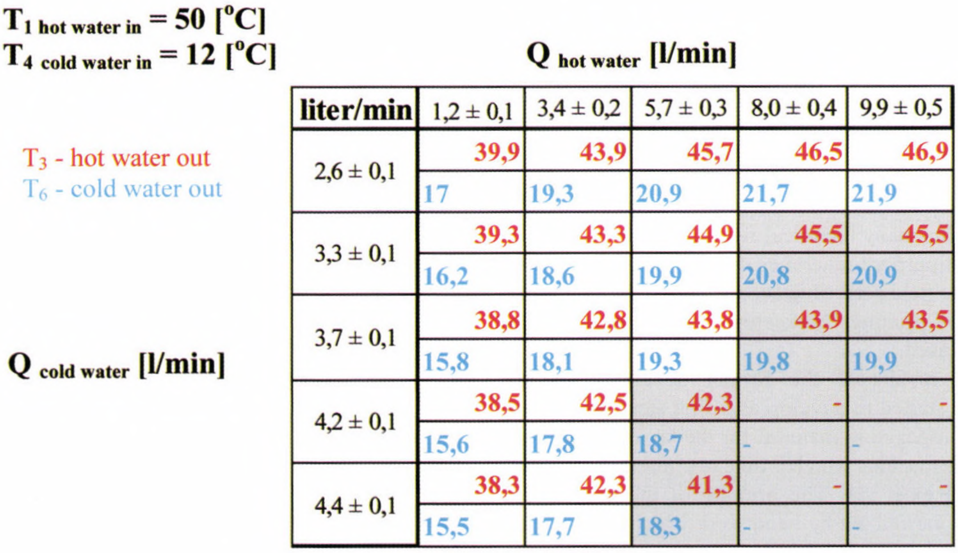


Figure 4. Hot water temperature change in the function of cold water mass flow (at 30°C-o inlet hot water and 12°C inlet cold water)



$T_{1\ hot\ water\ in}$ = 50 [°C]
$T_{4\ cold\ water\ in}$ = 12 [°C]

$Q_{hot\ water}$ [l/min]

T_3 - hot water out
T_6 - cold water out

$Q_{cold\ water}$ [l/min]

liter/min	1,2 ± 0,1	3,4 ± 0,2	5,7 ± 0,3	8,0 ± 0,4	9,9 ± 0,5
2,6 ± 0,1	39,9	43,9	45,7	46,5	46,9
	17	19,3	20,9	21,7	21,9
3,3 ± 0,1	39,3	43,3	44,9	45,5	45,5
	16,2	18,6	19,9	20,8	20,9
3,7 ± 0,1	38,8	42,8	43,8	43,9	43,5
	15,8	18,1	19,3	19,8	19,9
4,2 ± 0,1	38,5	42,5	42,3	-	-
	15,6	17,8	18,7	-	-
4,4 ± 0,1	38,3	42,3	41,3	-	-
	15,5	17,7	18,3	-	-

Figure 5. Limits of Armfield HT31 Tubular Heat Exchanger