Sprinkled heat exchangers in condensation and evaporation mode

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Abstract The paper presents a state of the art review of fundamental research of heat transfer process in liquid sprinkled heat exchangers placed in atmospheric and also in vacuum chamber. It compares the structure of atmospheric and vacuum stand. There are declared and then compared the first results of measurements. There is an evaluation of the influence of different stand's concepts and the proposals for further modifications of vacuum and atmospheric stand.

1 Introduction

It was ages ago when people started utilising cooling along with heat to preserve food. An example of that is The Plzensky Prazdroj company which used to harvest ice on ponds and then store it in cellars to keep beer cool. Many years has gone by since then leaving the job to modern cooling technology – the absorption cycle. It was launched in 2003 and its cooling capacity is 1.5 MW [2].

Another and, in fact, more widespread method in cooling technology is the application of the vapour compression refrigeration cycle. When compared to the absorption cooling cycle, it is more compact, it weighs and costs less for the same cooling capacity. On the other hand suffers from a shorter life span and being rather noisy. The absorption cycle only rotating component is a pump, which there are no special requirements about. Although the absorption cycle device is more capital cost intensive, its running costs are lower as the power consumption is about a fifth or a tenth of the compression cycle one. Hence the payback periods for both are approximately the same. For a closer description and comparison of both cycles, a reader is referred to [1].

2 Atmospheric stand

One of the key components of an absorption cycle is a heat exchanger that optimises the heat transfer process. The first produced experimental device operates at the atmospheric pressure and it concerns with various spacing and surface treatment of the heat exchanger tubes.

A tube bundle (2), in **Figure 1**, is mounted to a frame (1) may consist of up to 20 tubes of vertically aligned arrangement and various inclination. The tube spacing can range from 15 to 35 mm with 5 mm step. The cooling loop (tube bundle) flow rate can reach 310 l/h. Sprinkling water is pumped above the tube bundle through a distribution tube which has holes in it of 1.5 mm in diameter and 10 mm apart lengthwise. The tube bundle itself comprises copper tubes of 12 mm in diameter and various surface treatment. The ones tested were: smooth, sandblasted, and finned tubes.

The experimental set-up is fitted with four thermocouples that measure temperatures at the sprinkling water input and output. Two ways are employed to measure the flow rate. The instantaneous flow rate is measured by a flow meter (3) and the total flow meter by a water meter (4). A flow-through heater (5) heats up water to be sprinkled over the tube bundle; the water is, then, collected in a trough (6). The sprinkling water is a regular water from a water-supply network.

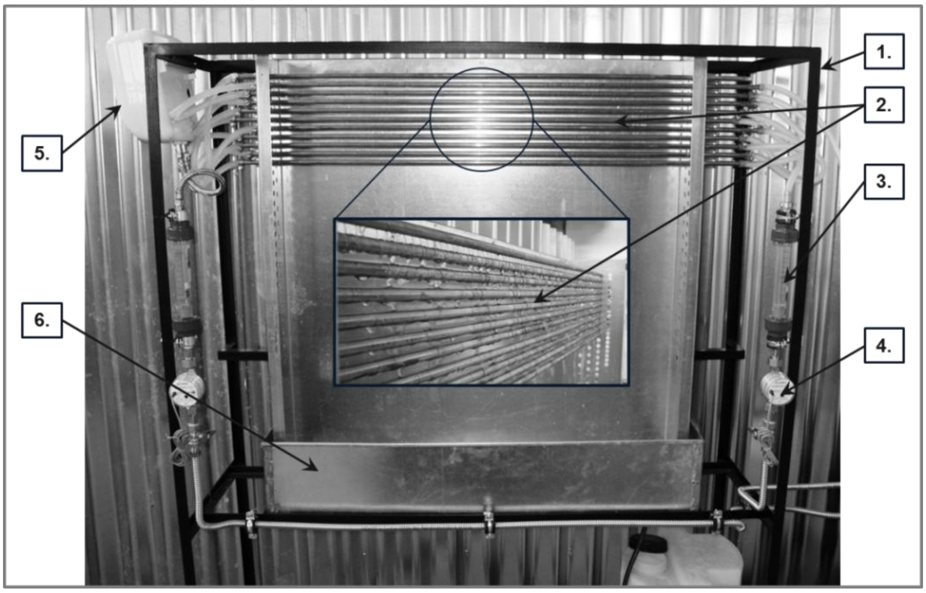

Fig.1 The atmospheric heat exchanger stand

The volume flow rate is determined based on the difference in between the both flow meter read outs at the beginning and end of the measurement. The procedure applies to all tested flow rates, tube spacing as well as tube surface treatments.

The heat loss of the sparkling water side of the heat exchanger was determined based on the temperature difference encountered with the lowest flow rate for various tube spacing and the cooling loop being shut off. At the maximum flow rate, i.e. 300 l/h, the temperature difference of the sparkling water entering and leaving the tube bundle is zero, which was proved by the measurement. The temperature differences resulting from the flow rates in between minimum and maximum were obtained by means of linear interpolation.

The heat loss at the refrigerant liquid side was determined employing the temperature difference obtained when the sprinkling loop was closed off. Along with the heat loss, the total amount of heat rejected and absorbed at various flow rates was acquired. Subtracting the total heat absorbed from the rejected one gives the actual amount of heat transferred between the sparkling water and refrigerant liquid. The investigated heat transfer coefficient was then calculated applying Newton's cooling law and Fourier's law of heat conduction.

3 Vacuum stand

The heat transfer research of a water sparkled tube bundle at atmospheric conditions is closely followed by development of the tube bundle situated inside a chamber where the pressure is kept below that of atmospheric by means of an ejector vacuum pump. In this way, both boiling and condensation over the tube bundle can be simulated using the chamber (**Figure 2**).

The vacuum stand chamber is essentially a cylindrical vessel 1.2 m in length fitted with three peep holes in which the tube bundle of 940 mm in length is located. Three closed loops are connected to the chamber. The ones on sides are designed to withstand 1 MPa of gauge pressure and supply the chamber with heated or chilled liquid. The third, central loop feeds in the sparkling water. Each loop includes a pump, a governing valve, a flow meter and a plate heat exchanger. The plate heat exchanger can be either connected to a hot water boiler to provide heat or to chilled water source when cooling is required. The gauge pressure loops are also fitted with expansion vessels and safety valves.

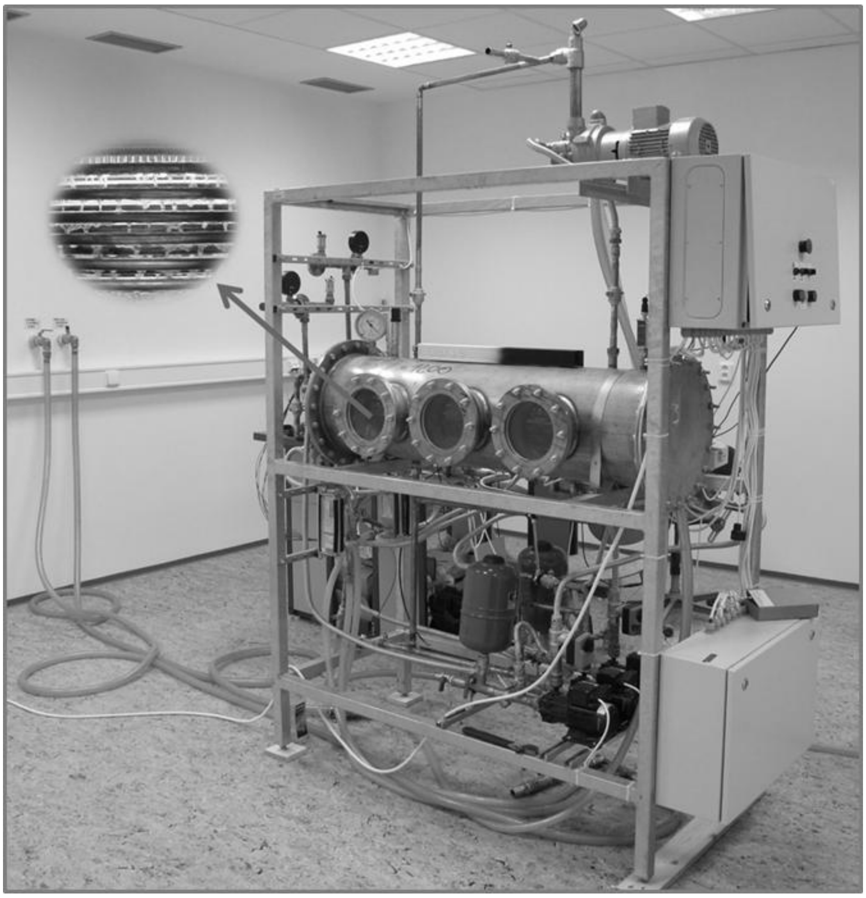

Fig.2 The vacuum heat exchanger stand

Thermal states of respective loops are measured with the use of thermocouples located at the inputs and outputs to the chamber. In order to detect the temperature gradient across the tube bundle, temperature is measured inside each loop using two thermocouples. The metal sheet enframing the tube bundle contains a set of holes of various spacing to allow for different tubes arrangement. Tubes of 12 mm in diameter make up the tube bundle. The distribution tube has 1 mm holes in it 9.2 mm apart along 940 mm of the tube.

The vacuum pressure is taken with three vacuum gauges; the first one (mercury type) serves for visual check-up. The second one is a digital one which covers all required vacuum range, though of low accuracy at very low vacuum levels. High accuracy of low vacuum pressure measurement – ranging from 0 Pa to 20 kPa – is attainable with the use of the third meter.

Regarding the flow rate measurement, it is performed employing Flomag 3 000 electromagnetic flow rate meter. Each loop is fitted with such a meter.

4 Results comparison

The heat transfer coefficient investigated as calculated from the experimental data for both the atmospheric (ATM) and vacuum (VS) stand, tube spacing 25 mm and various pressure levels (atmospheric and lower) are depicted in **Figure 3**.

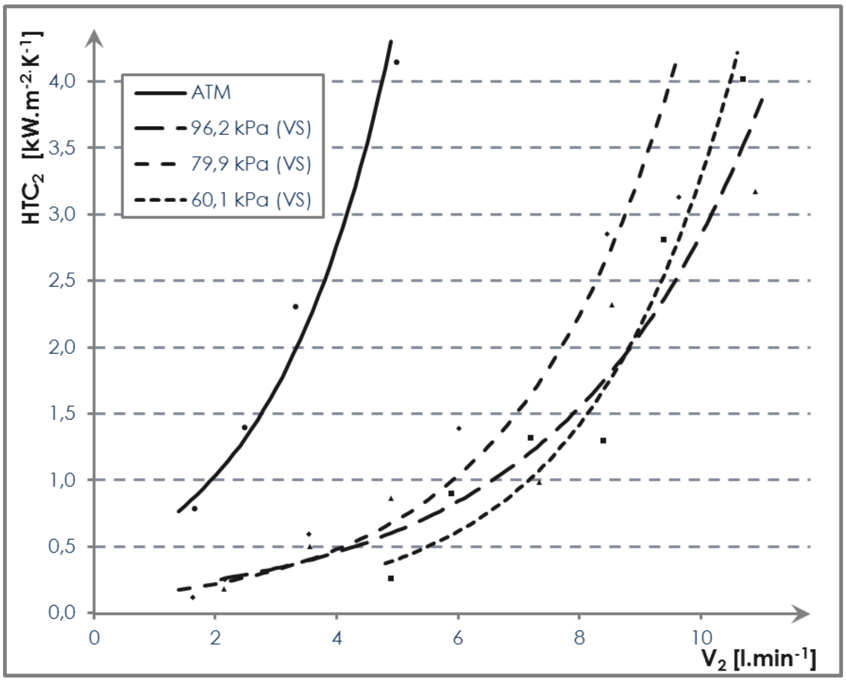

Fig.3 The heat transfer coefficient investigated as calculated from the experimental data for both the atmospheric (ATM) and vacuum (VS) stand

5 Conclusion

The contribution has outlined the development in the research of absorption cycles at the Brno University of Technology; namely, in the field of heat transfer connected with sprinkled tube bundles. A chart of preliminary data as obtained by employing both atmospheric and vacuum stand experimental data is provided as well. The values of the heat transfer coefficient were approximated by the exponential curve fitting method, which seems to be the best match to the contemporary theoretic background. When comparing the curves obtained at the atmospheric pressure condition, though the pressure at the vacuum stand was 96.2 kPa, there is a discrepancy among the individual values, but it corresponds to the measurement methods employed; the curve trends were confirmed. The temperature gradient along with the difference in the diameters of sparkling holes may be other factors influencing the measured values at the atmospheric pressure condition; the latter affects droplets formation and consequently the liquid film over the outer surface of the tubes. These will be subject to further investigation. Lowering the pressure inside the chamber led to the expected increase of the heat transfer coefficient over the surface of the sparkled tubes. Nonetheless, the trend of the increase does not change gradually and consistently, as one would suppose.

Acknowledgement

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