LABORATORY MEASUREMENTS OF FLAT-PLATE MILK COOLERS

Nejtek V., Fryč J., Konrád Z., Fryč J.

Department of Agricultural, Food and Environmental Engineering, Faculty of Agronomy, Mendel University in Brno, Zemedelska 1, 613 00 Brno, Czech Republic

E-mail: xnejtek@node.mendelu.cz

ABSTRACT

Measuring in laboratory conditions was performed with the aim to collect a sufficient quantity of measured data for the qualified application of flat-plate coolers in measuring under real operating conditions. The cooling water tank was filled with tap water; the second tank was filled with water at a temperature equivalent to freshly milked milk. At the same time, pumps were activated that delivered the liquids into the flat-plate cooler where heat energy was exchanged between the two media. Two containers for receiving the run-out liquid were placed on the outputs from the cooler; here, temperature was measured with electronic thermometer and volume was measured with calibrated graduated cylinder. Flow rate was regulated both on the side of the cooling fluid and on the side of the cooled liquid by means of a throttle valve. The measurements of regulated flow-rates were repeated several times and the final values were calculated using arithmetic mean. To calculate the temperature coefficient and the amount of brought-in and let-out heat, the volume measured in litres was converted to weight unit. The measured values show that the volume of exchanged heat per weight unit increases with the decreasing flow-rate. With the increasing flow-rate on the throttled side, the flow-rate increases on the side without the throttle valve. This phenomenon is caused by pressure increase during throttling and by the consequent increase of the diameter of channels in the cooler at the expense of the opposite channels of the non-throttled part of the circuit. If the pressure is reduced, there is a pressure decrease on the external walls of opposite channels and the flow-rate increases again. The cooling channels are flexible depending on pressure. The pressures were not measured in laboratory measurement. This feature could be utilised in practice: a pressure regulator on one side could regulate the flow-rate on the other side.

Key words: plate cooler, milk cooling

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INTRODUCTION

Milk is a valuable agricultural product and, after its finalisation, an irreplaceable component of human nutrition (ANDĚL, 2010). Milk contains a balanced score of proteins, fat, milk sugar, minerals, 14 trace elements, and numerous vitamins. To maintain its quality, milk is quickly cooled after drawing, from approximately 36°C down to 5°C. This process consumes a lot of energy due to the high difference in temperatures and the milk volume (PEŠEK, 1999). If it were possible to reduce the cost of cooling, e.g. by using preliminary flat-plate flow coolers, the saving would reflect in the overall costs per unit of milk. Another advantage is faster achievement of the required temperature than by standard means, and therefore higher degree of hygiene. In this way, producers could yield higher profits and enhanced competitiveness. The environmental perspective is important as well. With the ever-growing global population and increasing quality of people's lives a higher need for energy is expected, therefore energy-saving measures are becoming increasingly important.

OBJECTIVE

Experimental proving of the properties of a flat-plate cooler for optimal setting of milk and cooling water flow-rates used on farms.

MATERIAL AND METHODS

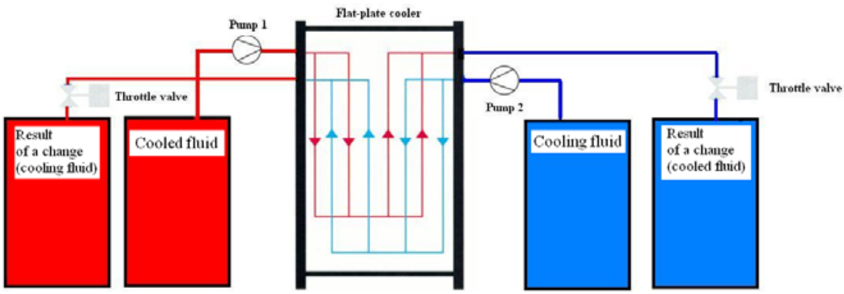

Fig.1 Diagram of laboratory measurements. Source [author]

Diagram of the flat-plate cooler connection for the purpose of measuring is presented in Fig. 1. The cooling fluid tank was filled with 13°C tap water; the second tank, which simulated freshly drawn milk, was filled with water at a temperature of 35°C.At the same time, the pumps were activated for 30 seconds. Fluids entered the flat-plate cooler where heat energy was exchanged between the two media. Two containers for receiving the run-out liquid were installed on the output pipes where temperature and volume were measured. Flow-rate was regulated by the throttle valve both on the side of the cooling fluid (Tab. 3, 4, Fig. 3) and on the side of the cooled liquid (Tab. 1, 2, Fig. 2).

Material used in the measurements:

Cooled and cooling water pumps: Manufacturer: AL-KO, Type: DRAIN 8001, Power input: 550 W, Performance: 10 000 l/h

Flat-plate flow cooler (counter-flows): Manufacturer: SAC Nederland B. V., Finish: Stainless steel, Type: 42, Heat-exchange area: 2.1m^2

Electronic thermometer: TESTO 922, Resolution: 0.1 °C, Temperature range: -50 to +1000°C,

Stop watch: Manufacturer: JVD, Type: VST31, Accuracy: 1/1000 sec.

The measurements were repeated five times for the respective regulated flow-rates; data shown in tables are calculated as arithmetic means from the measured values. Volume measured in litres was converted to weight unit in order to calculate the amount of brought-in and let-out heat Q and temperature coefficient K. (GRODA et al., 2008)

RESULT AND DISCUSSION

Comparing the resulting values with parameters provided by the manufacturer, we can conclude that the values were achieved during the measurements. For the type of the used flat-plate cooler (Type 42) the manufacturer claims milk temperature of milk on the output by 2 – 4°C higher than the temperature of cooling water on the input at a flow-rate of 4,000 litres of milk per hour. (SAC, 2013, [online]) In our case, this temperature difference ranged near the upper limit provided by the manufacturer. Graphs (Fig. 2, 3) demonstrate that the volume of exchanged heat per weight unit increases with the decreasing flow-rate. The measured values show that with the increasing flow-rate on the throttled side the flow-rate increases on the side without the throttle valve. This phenomenon is caused by pressure increase during throttling and by consequent increase of the diameter of channels in the cooler that reduce the diameter of adjacent channels with non-throttled liquid. With the decreasing pressure, there is a pressure decrease on the external walls of the opposite channels and the flow-rate increases. This property of the cooler could be utilised in practice when a pressure regulator on one side would regulate flow-rate on the other side and vice versa (GÁLIK, 2012).

Tab. 1 Change of cooling water parameters on passing through the cooler (cooled water throttling regime); source [author]

T_1 [°C]	T_2 [°C]	m [kg]	Q [J]	P [W]	i [$J.kg^{-1}$]	K [$W.m^{-2}.K^{-1}$]
13,0	17,4	22,88	420884	14029	18392	969
13,0	23,6	23,15	1032664	34422	44600	2805
13,0	28,9	23,95	1598906	53296	66754	4265
13,0	30,3	24,15	1746498	58216	72314	4584
13,0	30,2	26,65	1923580	64119	72188	4818

Tab. 2 Change of cooled water parameters on passing through the cooler (cooled water throttling regime); source [author]

T_1 [°C]	T_2 [°C]	m [kg]	Q [J]	P [W]	i [$J.kg^{-1}$]	K [$W.m^{-2}.K^{-1}$]
35,0	14,7	4,59	388204	12940	84561	894
35,0	15,5	11,51	937927	31264	81510	2547
35,0	18,8	23,98	1616941	53898	67423	4313
35,0	20,6	31,07	1866131	62204	60066	4898
35,0	21,2	35,03	2010409	67013	57391	5036

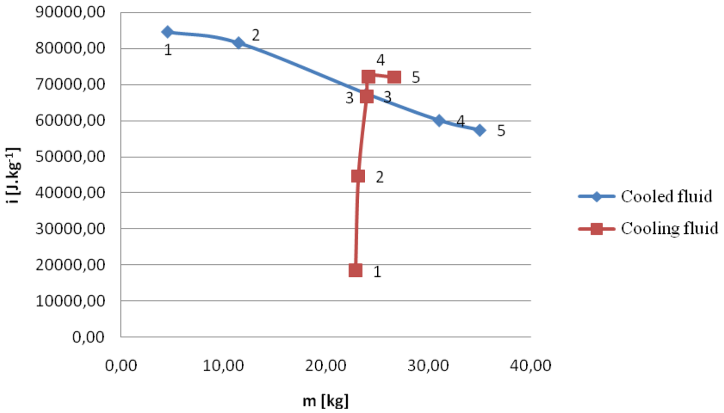

Fig.2 Graph of dependence of enthalpy change between the cooling and cooled fluid on the flow; source [author]

Tab. 3 Change of cooled water parameters on passing through the cooler (cooling water throttling regime); source [author]

T_1 [°C]	T_2 [°C]	m [kg]	Q [J]	P [W]	i [$J.kg^{-1}$]	K [$W.m^{-2}.K^{-1}$]
35,0	30,0	24,75	513826	17127	20760	1402
35,0	26,7	24,68	856247	28541	34694	2332
35,0	20,1	24,98	1548843	51628	62003	3962
35,0	18,4	24,88	1719440	57314	69109	4411
35,0	17,7	27,28	1968924	65630	72174	4964

Tab. 4 Change of cooling water parameters on passing through the cooler (cooling water throttling regime); source [author]

T_1 [°C]	T_2 [°C]	m [kg]	Q [J]	P [W]	i [$J.kg^{-1}$]	K [$W.m^{-2}.K^{-1}$]
13,0	33,9	5,86	511941	17064	87362	1397
13,0	33,2	9,85	833067	27768	84575	2269
13,0	29,6	21,52	1499226	49974	69666	3835
13,0	28,0	27,67	1738764	57958	62839	4461
13,0	26,8	35,23	2037116	67903	57823	5136

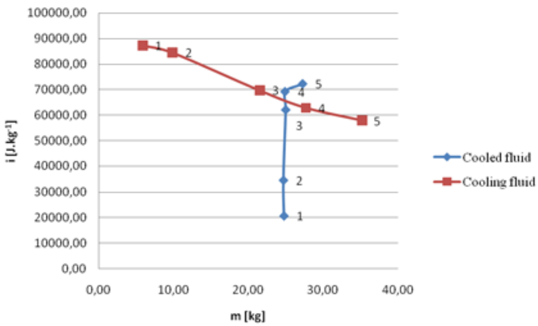

Fig. 3 Graph of dependence of enthalpy change between the cooling and cooled fluid on the flow; source [author]

CONCLUSIONS

We can deduce from the measured values that using flat-plate milk coolers in practice could bring a major cost-reduction of electricity needed for the cooling aggregate. Other presumed benefits include lower cost of the cooling system maintenance and repairs due to lower load, longer service life of the entire system (GÁLIK et al., 2006), positive impacts on the quality of milk in terms of rate of its cooling down to the required temperature. It is also possible to consider using heated water for watering the milking cows (this is beneficial especially in winter) as well as for washing, floor hygiene, etc.[5]

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