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Counterflow Heat Exchanger

Figures and Tables

Table 1.

Case	Flow rate		C_r	U_l (W/m^2K)	ε			$T_{s,o}$ (°C)		
	Q_c (gpm)	Q_h (gpm)			Eq 13 or 14	Eq. 9	Δε (%)	measured	Eq. 17	ΔT (% diff in Kelvin)
1a	5.0	3.0	0.60	1929	0.2588	0.2608	0.80	38.0	37.5	0.17
1b	5.0	2.5	0.50	1893	0.2980	0.3011	1.04	36.5	35.8	0.22
2a	5.0	1.5	0.30	1798	0.4319	0.4459	3.25	32.9	31.0	0.64
2b	3.0	3.0	1.00	1451	0.1973	0.1984	0.55	40.6	40.2	0.12

Table 2.

Case	Flow rate		Heat transfer rate (W)			Heat transfer modes (W)		
	Q_c (gpm)	Q_h (gpm)	q_c (eq. 1)	q_h (eq. 2)	% diff	q_{conv}	q_{rad}	Δ/q_c (%)
1a	5.0	3.0	6927	6519	5.89	7.40	4.29	0.169
1b	5.0	2.5	6709	6271	6.52	5.62	3.19	0.131
2a	5.0	1.5	5979	5207	12.93	5.32	3.01	0.139
2b	3.0	3.0	5469	5163	5.60	5.95	3.39	0.178

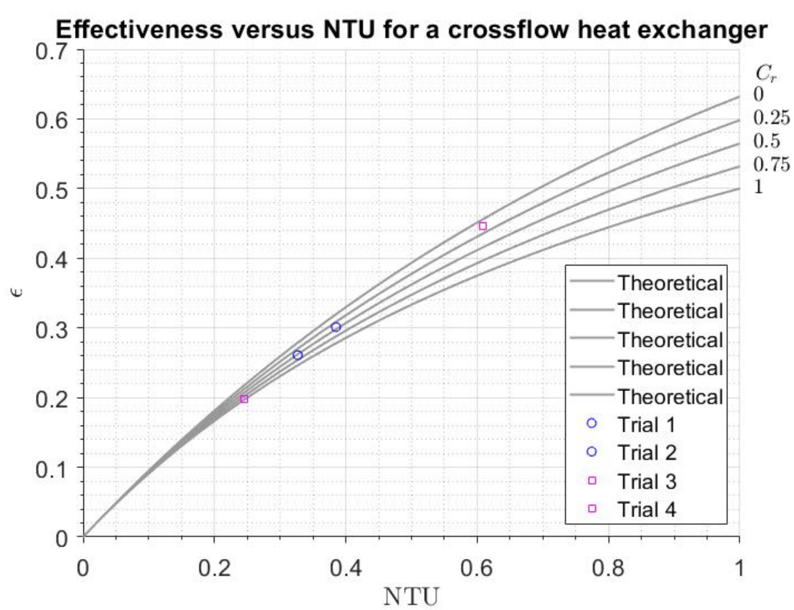

Figure 1. ε vs. NTU accepted values with this experiment's values overlaid

Short-Answer Questions:

1. Discuss the reasons for any discrepancies observed between the measured and calculated shell-outlet temperatures listed in Table 1.

The actual measured temperatures are all slightly higher than the calculated outlet temperatures, but by less than 1% (in kelvin). This is counterintuitive because it seems as though losses along the exchanger would cause the actual temperature to drop lower than the calculated one. Inspecting the equation used to calculate the outlet temperature, there must be error in either the ratio of specific heats (i.e., the water specific heat or volume flow rate) or the inlet temperature measurements. There won't be error in the effectiveness because that would be circular reasoning. The ε-NTU method is conservative, since it considers the minimum heat capacity rate.

2. Discuss any experimental conditions that you think could cause the disparities in the effectiveness ε values listed in Table 2.

There are a few sources of error in the experimental setup. One is radiative heat losses from the heat exchanger shell. Another is convective heat losses from the shell. There is always the possibility of error in temperature measurement and non-uniform flow cross-sectional temperature. It's important to notice that the measured effectiveness values are *all* lower than the theoretical ones, so the main cause of discrepancy is most likely losses. The estimated losses from convection and radiation are not enough to make up for the discrepancy, however. They are similar in magnitude and together make up no more than 0.17 % of the total heat rate (see table 2). The convection calculation was made assuming an air flow speed of 0.5 m/s, which is generous.

3. How well do your effectiveness ε values plotted from Figure 1 above agree with the theoretical performance curves? Your response should include a percent difference for each test case and describe any trends observed, i.e., are the more errors with lower/higher NTU or lower/higher C?

The measured ε are very close to the theoretical performance curves. The highest difference is 3.25% for trial 3, while trials 1, 2, and 4 are only 0.80, 1.04, and 0.55 % off, respectively. For all trials, it holds true that the higher C_r is, the closer ε is to the theoretical curve, and vice versa. Inversely, the higher NTU is, the less accurate the measured effectiveness values are.