To: Doctor Dahlke; Brewing Engineer Team

From: Nguyen Khoa Bui

Re: Characterization of heat exchanger for purchase

Dear Doctor Dahlke and Brewing Engineering Team,

A small-scale tube-and-shell heat exchanger was setup according to The Lab Manual to characterize heat transfer properties for various cold- and hot-side flowrates in co- and countercurrent flow (Heat Exchanger Experiment). For both flows, the overall heat transfer coefficient U is not impacted by change in hot-side flowrate but varied with change in cold-side flowrate. This may be due to hot-side flowrates were two to ten times larger than cold-side flowrates for many runs, which minimize the hot-side resistance impact on U. This make determining fouling effects not possible due to disagreement in constant c = 0.2 for countercurrent and infeasible value c = - 1.64 for co-current during parameters fitting. For both flow conditions, experimentally determined heat transfer coefficient hiExp do not behave as expected when compared to that of Sieder-Tate correlation hiS-T. The data collected are considered accurate as all normalized Qc+ Qh are within the error propagation ranges. We concluded our data may only be used for countercurrent flow, limited to large hot-side to cold-side flowrate difference. We strongly recommend the brewing team to reconduct the experiment for a smaller flowrate difference between both sides and parameters should be re-fit.

Cc: Abdullah Alkazrai, Saeed Alharmoodi, Khalid Alsinan

Encl: 5 figures

Chart, scatter chart

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***Figure 1.*** *plot of experimental and model overall heat transfer coefficient, UiExp and UiModel versus mass velocity of tube-side Gi for various shell-side mass velocity Gs in countercurrent condition. Here, , where While b value is close to Sieder-Tate expected value of b = 0.8, e value deviated greatly from Sieder-Tate value e = 0.55. These parameters result in all model trend for various Gs to clumped up into one line. Error bars for elements with repeated runs are presented and small compared to data point.*

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***Figure 2.*** *plot of tube-side experimental UiExp and model UiModel overall heat transfer coefficient versus mass velocity of tube-side Gi for various shell-side mass velocity Gs in co-current condition. Here, , where These parameters result in all model trend for various Gs to clumped up into one line. Both b and e values deviate greatly from expected values from Sieder-Tate where b = 0.8 and e = 0.55. Model yield negative value for c,* which is physically impossible despite proper fitting. Error bars for elements with repeated runs are presented and small compared to data point.

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***Figure 3.*** *log-log plot of tube-side experimental hiExp and Sieder-Tate correlation hiS-T heat transfer coefficient versus mass velocity Gi for countercurrent condition. Here, where and . Both models portray the same trends on the log-log scale, but hiExp values are four to ten magnitudes larger than hiS-T, scale inversely with Gi.*

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***Figure 4.*** *log-log plot of tube-side experimental hiExp and Sieder-Tate correlation hiS-T heat transfer coefficient versus mass velocity Gi. for co-current condition. Here, where and . hiExp start off higher than hiS-T at lower Gi but increase slower. This leads to an intersection point between the two model at .*

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***Figure 5.*** *Plot of normalized heat rate versus number of runs. All data point is within error tolerance with the normalized axis. Points deviations are noticed to be relatively small compared to error bars. Points with spiked error bars are of runs where Gi are around 10 times smaller than Gs. Errors are smallest for run with similar G­I to Gs. This shows that the data may be accurate, but is not precise, which is reflected through the unusual model fitting for co- and countercurrent.*

Appendix:

# References:

(n.d.). *CBE 424 Lab Manual: Heat Exchanger Experiment.*

Sample calculation:

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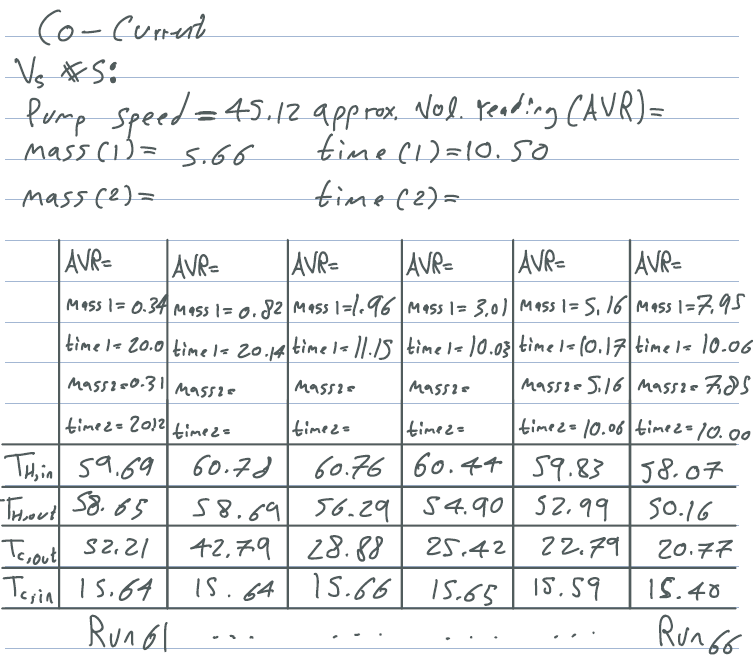
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