CLB 321: Laboratory

Heat Transfer

Experiment C: 28 August and 4 and 6 September 2019

Developing a correlation for the overall heat transfer coefficient

Authors:

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1. Introduction

The University of Pretoria has two heat exchanger test facilities, namely a plate and frame heat exchanger (or plate heat exchanger, PHE) test facility and a shell and tube (STHE) test facility that are used to demonstrate the principles of heat transfer and piping systems design with fluid movers.

The PHE facility comprises two plate heat exchangers which may be operated apart from one another or together by selecting the appropriate piping and valve configurations. Both exchangers are able to operate co- or counter-currently. A piping and instrumentation diagram of the PHE apparatus is provided in Appendix A. Figure A1 shows the overall configuration of the PHE facility while Figure A2 shows the configuration when the first heat exchanger (PF-01) is configured to operate counter-currently. A design drawing for the plate heat exchanger is provided in clickUP as well as the dimensions and materials of construction of both heat exchangers. Operating instructions for the heat exchanger test rigs are also available in clickUP.

Note that currently the radiator mentioned in the P&IDs is by-passed and that the temperature of the cold utility supply is being maintained by adding cold water to the supply tank and draining the excess water from the tank.

The STHE facility comprises two straight tube heat exchangers, one with a single pass tube-side construction and the other with a two pass tube-side construction. Both heat exchangers can be configured to operate co- or a counter-currently with respect to the first tube pass. The P&ID of the apparatus is also included in Appendix A, Figure A3. The configuration shown is for running either one of the heat exchangers counter-currently.

The main purpose of the assignment is to develop empirical equations to correlate the overall heat exchange coefficients of the STHE and the PFHE operating in counter current mode as functions of the cold and hot utility flow rates.

2. Proposed experiments

2.1 PHE facility

<u>Objective 1</u>

The first objective will be to obtain the pump curve of the two cold utility pumps, namely CPP-03 and CPP-04. These pumps are installed to operate in series which makes it possible to measure the pump curves simultaneously.

The output required from the test is a graph showing the differential pressure created by each pump in units of meter water as a function of the flow rate through the pump.

<u>Objective 2</u>

The second objective is to develop an empirical equation describing the overall heat transfer coefficient as a function of the hot and cold utility flow rates when the heat exchanger utility streams are flowing counter-currently.

The form of the empirical equation must be as follow:

$$U = a + b\dot{V}_C + c\dot{V}_H + d\dot{V}_C\dot{V}_H$$

Where a, b, c and d are empirical constants and $\dot{V}_C$ and $\dot{V}_H$ are the volumetric flowrates of the cold and hot streams respectively.

This can be done if measuring overall heat transfer coefficient at a number of different cold utility flow rates while the hot utility flow rate is kept constant and also measuring the overall heat transfer coefficient at different hot utility flow rates while the cold utility flow rate is kept constant.

It is suggested that a 4X4 matrix of combinations of hot and cold utility flow rates be used.

Comment on the accuracy of the empirical equation fitted to the data.

Note: Similar experiments are required for the STHE.

2.2 STHE facility

<u>Objective 1</u>

The first objective will be to determine the pressure drop over the tube side of the single pass STHE. The flow through the tube side is to be varied and the pressure drop over both tube side passes are to be measured and reported as a function of the volumetric flow rate.

<u>Objective 2</u>

As with the PHE facility, the second objective is to develop an empirical equation describing the overall heat transfer coefficient as a function of the hot and cold utility flow rates when the heat exchanger utility streams are flowing counter-currently.

3. Heat exchanger design equations

The overall heat transfer rate of a heat exchanger is given by the following equation:

$$Q = UA\Delta T_{lm} \qquad 1$$

with:

Q	The heat transfer rate, W
U	The overall heat transfer coefficient, W/m^2.°C
A	Overall heat transfer area, m^2
ΔT_{lm}	Log mean temperature difference, °C

The log mean temperature is derived from the inlet and outlet temperatures of the hot and cold streams:

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{ln\left(\Delta T_1 / \Delta T_2\right)}$$

Where ΔT_1 is the temperature difference between the hot and cold streams on one side of the heat exchanger and ΔT_2 is the temperature difference between the hot and cold streams on the other side of the heat exchanger. This is further illustrated in Figure 1 for clarification.

Figure 1: Assignment of temperatures for calculating the LMTD.

4. Outputs from experiments

Each group should prepare the following:

1. An oral presentation of no more than 20 min should be prepared for presentation with both groups present. An additional discussion with each group will also take place during the presentations. Arrange that at least two members of the group make the presentation together.
2. Secondly, a formal report with an introduction, theory, experimental apparatus, results, discussion and finally conclusions and recommendations should be completed in accordance with the Department's Guidelines and Rules for Writing Technical Reports and Papers.

Copies of the formal report and the presentation (both in pdf format) must be loaded onto clickUP before or on the day of making the oral presentation.

5. Recommended Literature

Cengel, YA (2006) Heat and Mass Transfer: A Practical Approach, Third Edition, McCraw-Hill, New York.

Sinnott, RK (2005) Coulson and Richardson's Chemical Engineering Design Volume 6, Fourth Edition, Elsevier Butterworth-Heinemann, Oxford.

Appendix A: P&IDs for the PHE and STHE test facilities

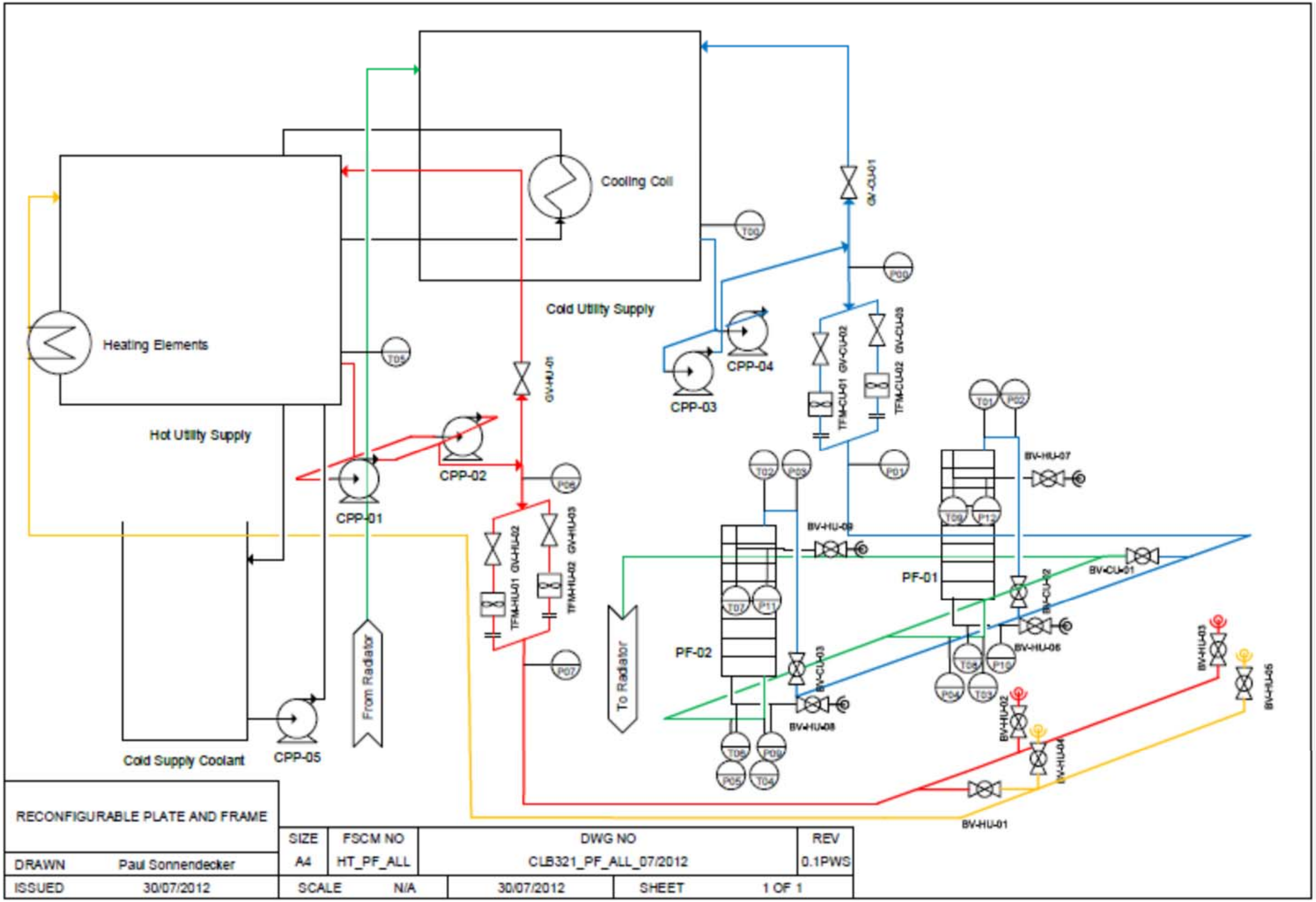

Figure A1: P&ID of the PHE apparatus (cold utility and hot utility piping systems shown in blue/green and orange/red respectively).

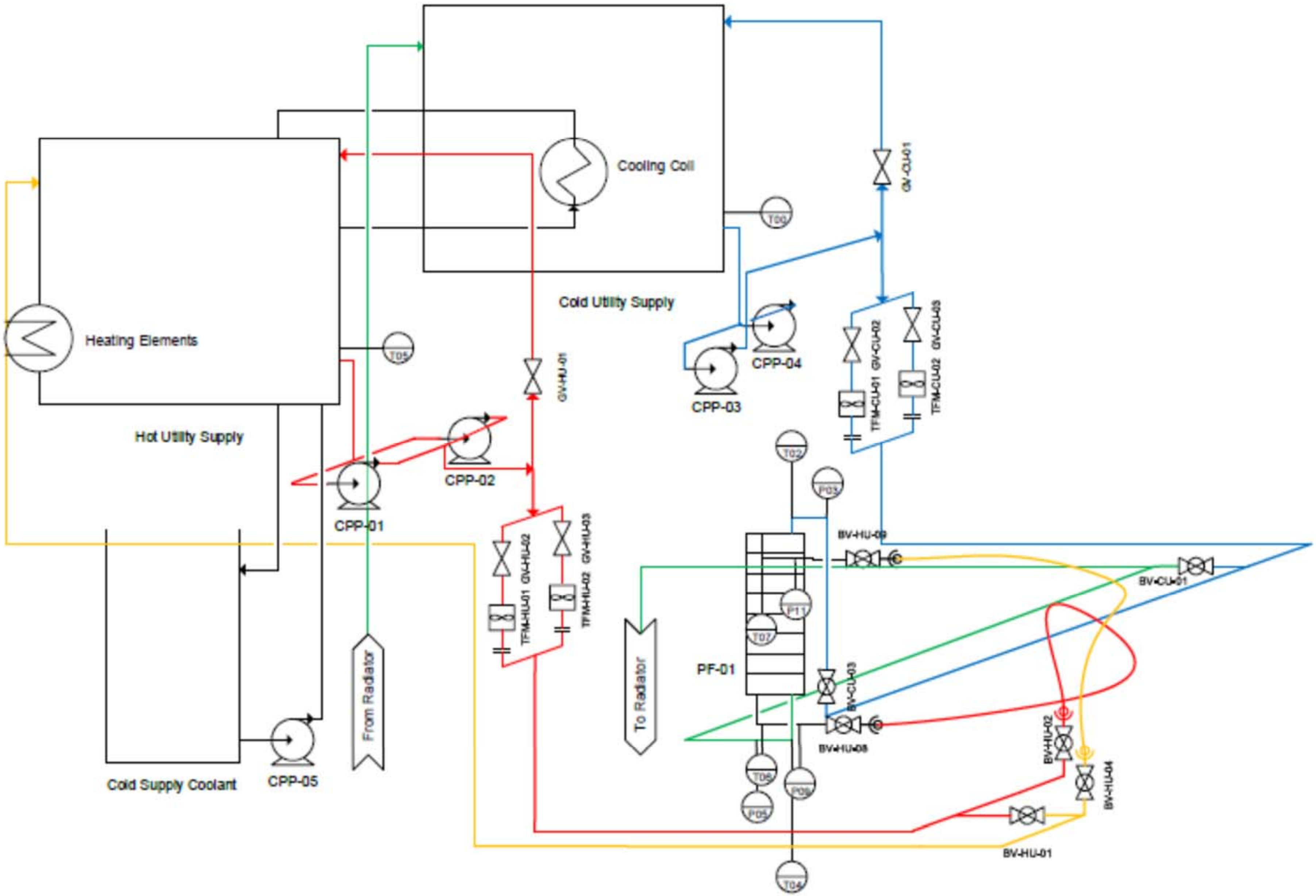

Figure A2: P&ID for the PHE PF-01 operated with a counter-current configuration.

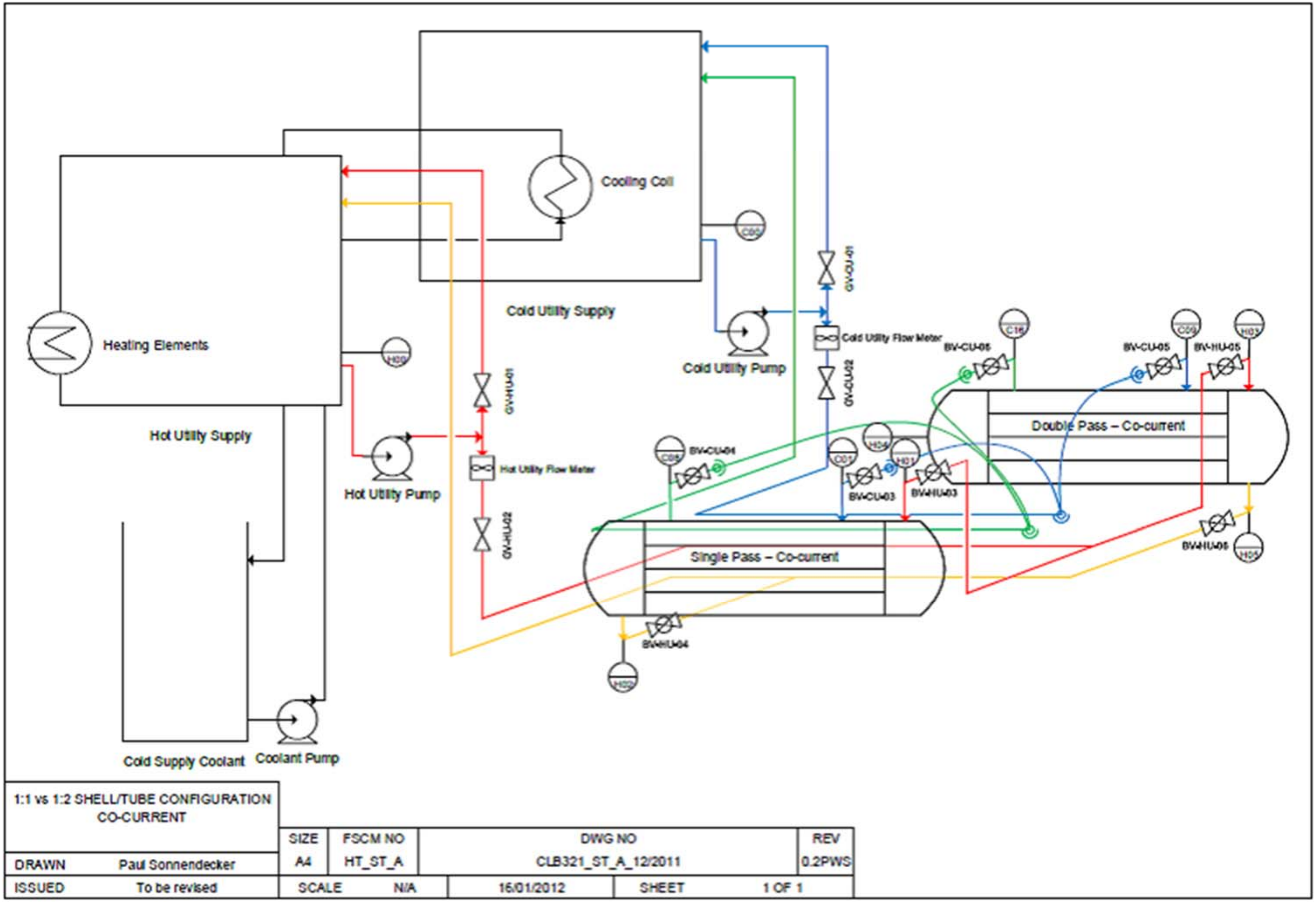

Figure A3: P&ID of the STHE apparatus (cold utility and hot utility piping systems shown in blue/green and orange/red respectively).