CLB 321: Laboratory

Heat Transfer

Experiment A: 31 July and 2 August 2019

Characterizing the dynamics and operational limits of heat exchanger test facilities

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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.

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.

In order to plan experiments using the test facilities, it is necessary to understand the dynamics and limitations of each facility.

In the programme to be undertaken on 26 July, one of the two heat exchangers for both facility are to be tested.

2. Proposed experiments

2.1 PHE facility

Objective 1

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.

Objective 2

The second objective will be to determine the overall heat exchange coefficient of the PHE and demonstrate how this changes as a function of the hot and cold utility flow rates. To measure this, the hot utility flow rate is to be kept constant while changing the cold utility flow rate and vice versa.

When changing from one operating condition to the next, the feed temperatures of the cold and hot utilities will change with time. Apart from measuring the overall heat transfer coefficient over time, it is required to determine the rate at which the system changes and to what steady state conditions the hot and cold utility supplies will tend towards.

Essentially, it is required to know how long it takes to do a test to measure the overall heat transfer coefficient and what the operating limitations in terms of maximum flow rates are before the cold utility supply becomes too hot and likewise before the hot utility supply becomes too cold.

2.2 STHE facility

Objective 1

The first objective will be to determine the pressure drop over the tube side of the two 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.

Objective 2

As with the PHE facility, it will be required to determine the overall heat transfer coefficient of the heat exchanger and to demonstrate how it changes as a function of the hot and cold utility flow rates. To measure this, the hot utility flow rate is to be kept constant while changing the cold utility flow rate and vice versa.

When changing from one operating condition to the next, the feed temperatures of the cold and hot utilities will change with time. Apart from measuring the overall heat transfer coefficient over time, it is required to determine the rate at which the system changes and to what steady state conditions the hot and cold utility supplies will tend towards.

Essentially, it is required to know how long it takes to do a test to measure the overall heat transfer coefficient and what the operating limitations of the test facility are in terms of maximum flow rates before the cold utility supply becomes too hot and likewise before the hot utility supply becomes too cold.

3. Heat exchanger design equations

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

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

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.

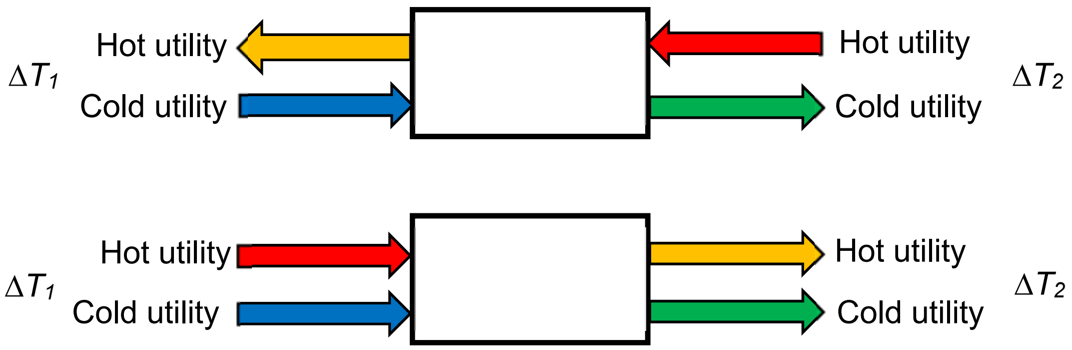

Figure 1: Assignment of temperatures for calculating the LMTD.

4. Outputs from experiments

Each group should prepare the following:

1. 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. Discuss and interpret trends in the measurements and comment on the expected accuracy of measurements.
2. Secondly, a 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.

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

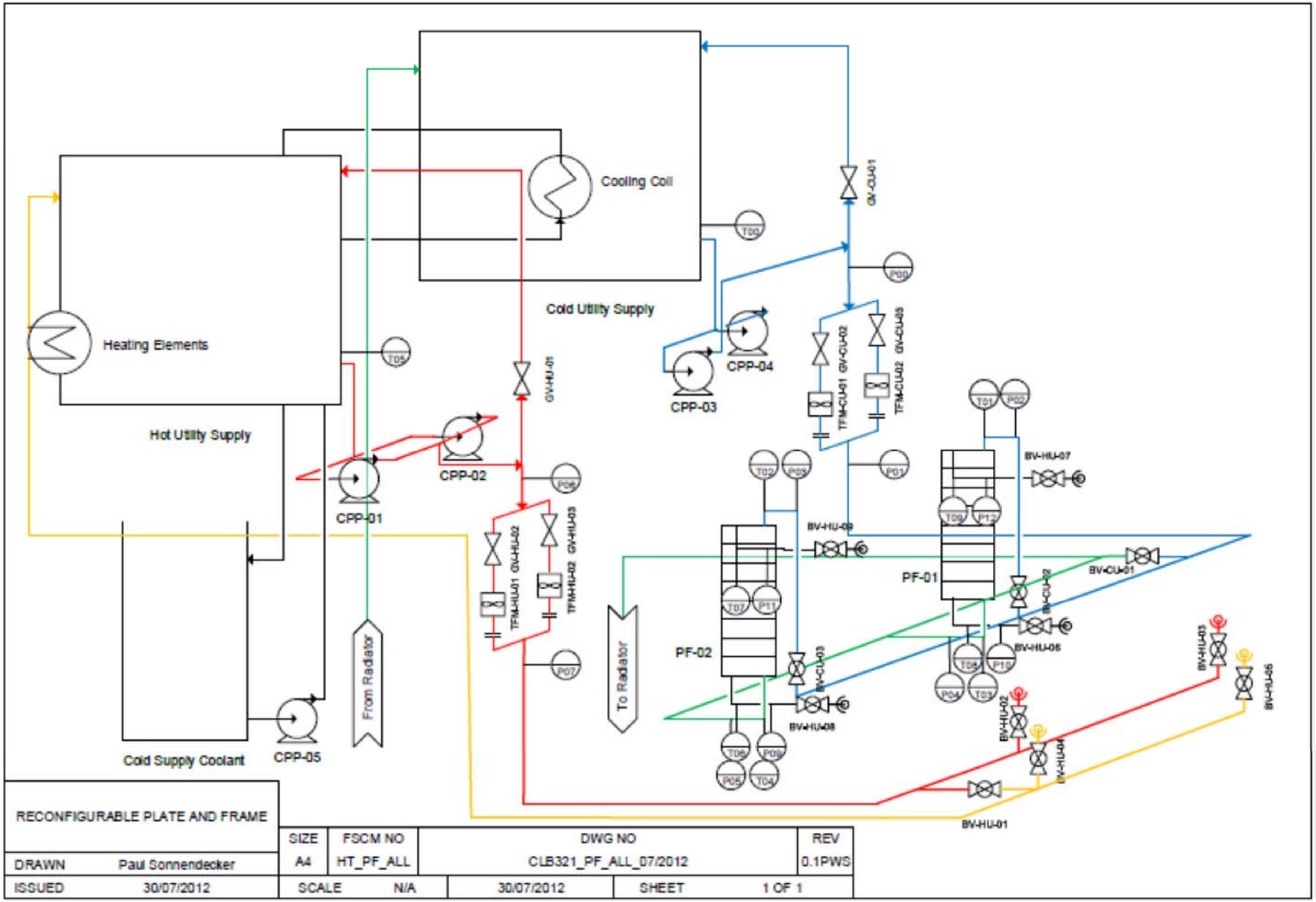

Figure A1: P&ID of the PHE apparatus (cold utility and hot utility piping systems shown in blue/green and orange/red respectively).

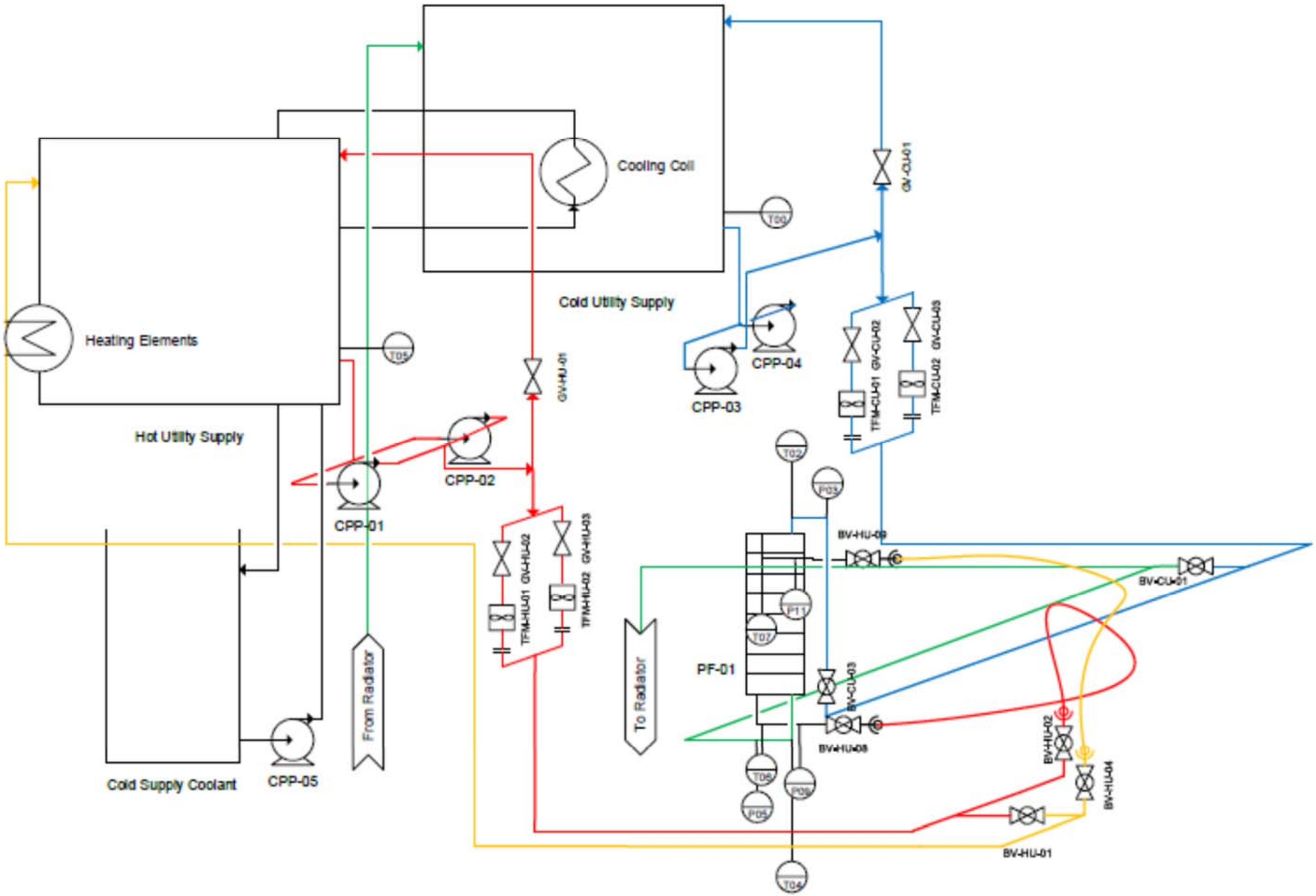

Figure A2: P&ID for the PHE PF-01 operated with a countert-current configuration.

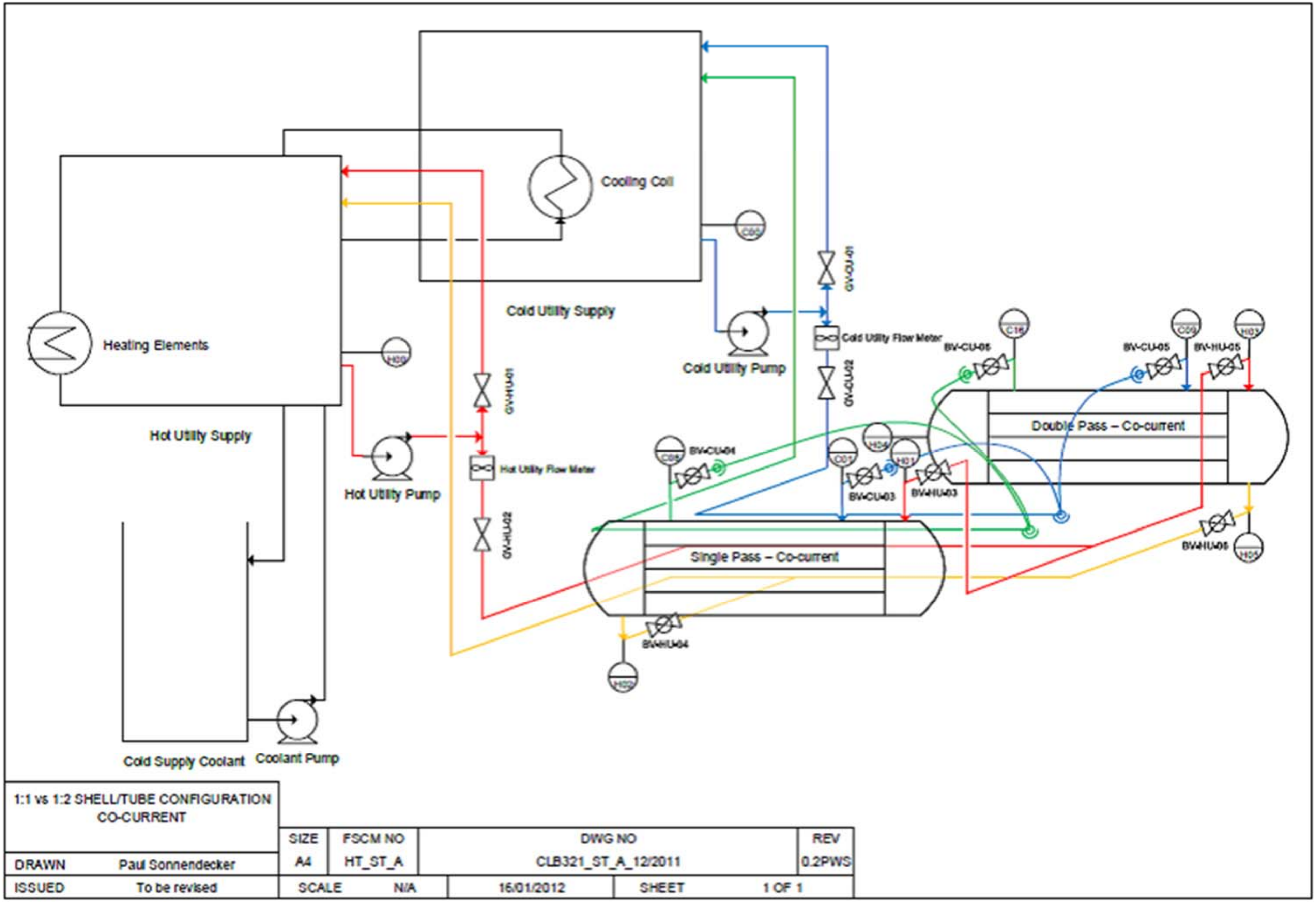

Figure A3: P&ID of the STHE apparatus (cold utility and hot utility piping systems shown in blue/green and orange/red respectively).