Solar Thermal Collector Design of Experiments for the NAU Renewable Energy Laboratory

NAU Northern Arizona University Mechanical Engineering

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Abstract

The Northern Arizona University Mechanical engineering department's renewable energy course is implementing new labs to inform students about renewable energy sources. These labs are intended to allow for hands-on learning and practical application experiences for students. The department has an evacuated tube solar thermal collector with a manufacturer-reported efficiency curve. The team designed an experiment that compares manufacturer performance efficiency values to experimental performance. To measure the efficiency experimentally, the team designed a solar thermal system using this collector along with necessary data collection instrumentation. Student operation, weather, and safety were considered while designing the testbed and operation procedures. The resulting system is successful in heating a glycol loop that then heats a load of water through a heat exchanger. From this, students can calculate efficiency values of the collector to compare to the reported values, analyze the system's performance in varying conditions, economic impact, and sustainability.

Requirements

Testbed	Design and create an experimental test bed housing an evacuated tube solar collector. Consider system expansion in the form of additional solar collectors and lab variations.
Lab Proceedure	Create lab procedure for a new ME 451 lab applicable to ME & Non-ME majors alike.
Efficiency Comparison	Compare reported from the manufacturer with collected experimental data for the evacuated tube system.
Use Collector On Hand	Utilizing existing evacuated tube solar thermal collectorto allow for benchmarking with a physical product.
Master Data Set	Run the system as described in the lab procedure to record a master set of dataand report system efficiency upon findings.

Methods

The team designed a close loop system complete with protective elements, instrumentation, options for an induced thermal load and system expansion.

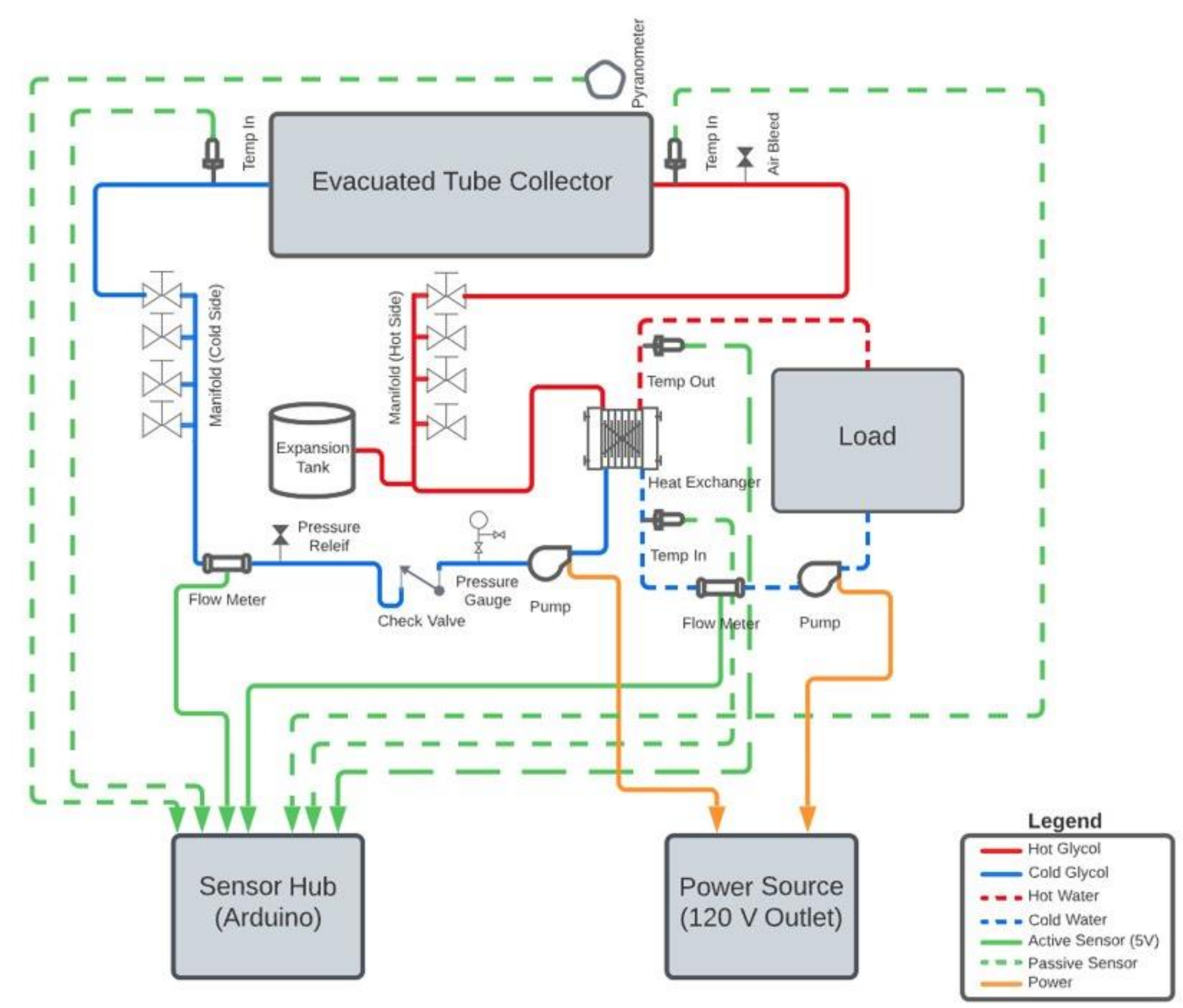

Figure 1: Process Diagram of Solar Thermal Testbed

Results

The efficiency of the collector is calculated using equation 1. Where $\dot{m}$ is flow rate, C_p is heat capacitance, ΔT is the difference in temperature across the inlet and outlet of the collector, A_c is the gross area of the collector, and I_c is solar irradiance.

$$\eta_c = \frac{q''_{conv}}{q''_{rad}} = \frac{\dot{m} \cdot C_p \cdot \Delta T}{A_c \cdot I_c} \qquad (1)$$

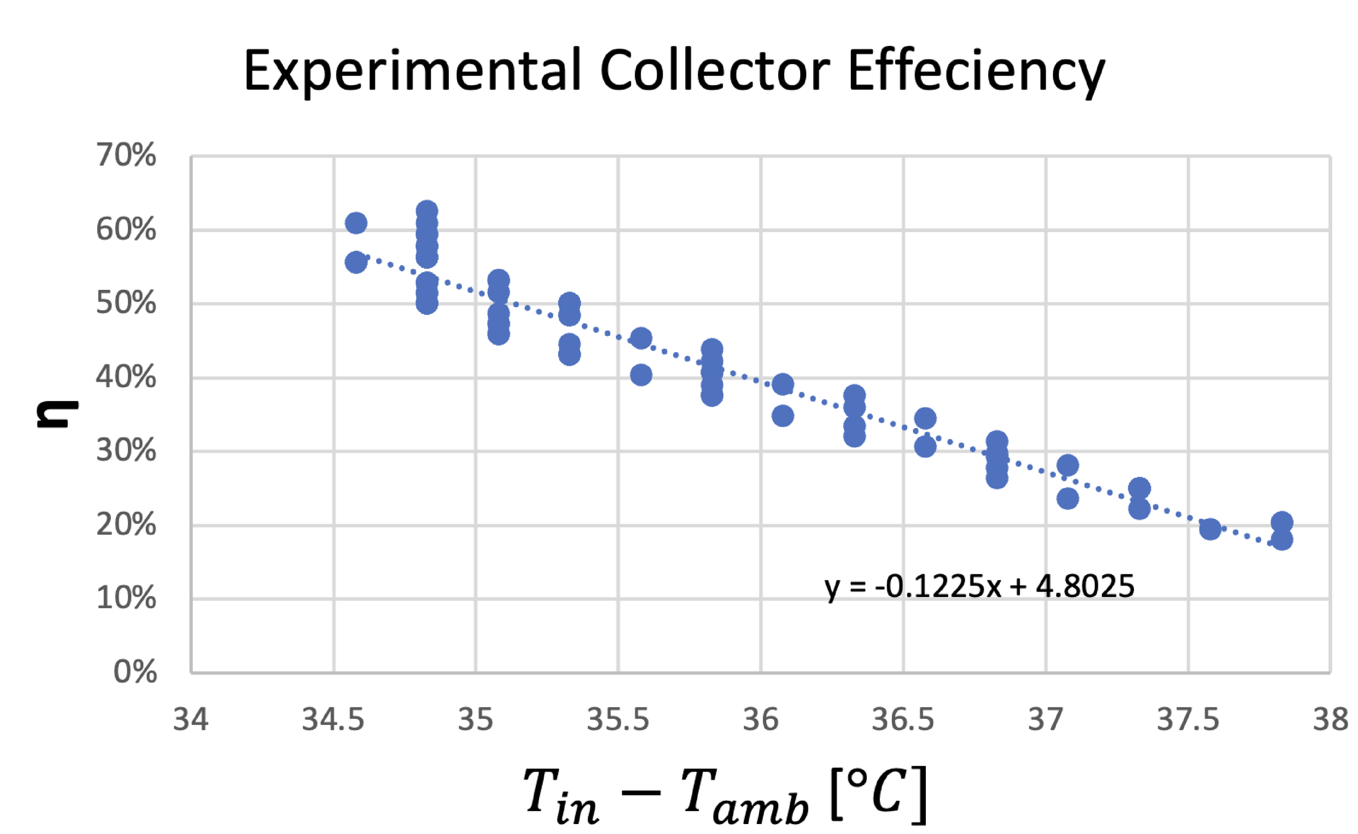

Figure 2: Plot of Efficiency and Temperature Difference in Collector Inlet and Ambient

Conclusion

The team successfully created a testbed using the provided evacuated tube solar collector. Using the newly constructed solar thermal testbed the necessary parameters can be measured using the instrumentation within the system: thermocouples, flow meters, and a pyranometer. Using the data from these sensors the team calculated the efficiency values of the collector. Students taking the Mechanical Engineering Renewable Energy Course will be expected to collect and interpret data from the solar thermal system. Students will be encouraged to think about what the efficiency results imply about the collector and system. With that, students will consider economic impact, and sustainability. Ultimately, the team hopes that the new solar thermal system will contribute to an enriching hands-on learning experience.

Future Work

The testbed can be expanded upon to have a variety of solar concepts tested and used in the education of students. Options include but are not limited to comparing the performance factors of different levels of solar thermal technology, Analyzing the performance of collectors at various angle of tilt. The system should stand the test of time however everything is prone to failure and revision.

Figure 3: Fully Constructed Solar Thermal Testbed

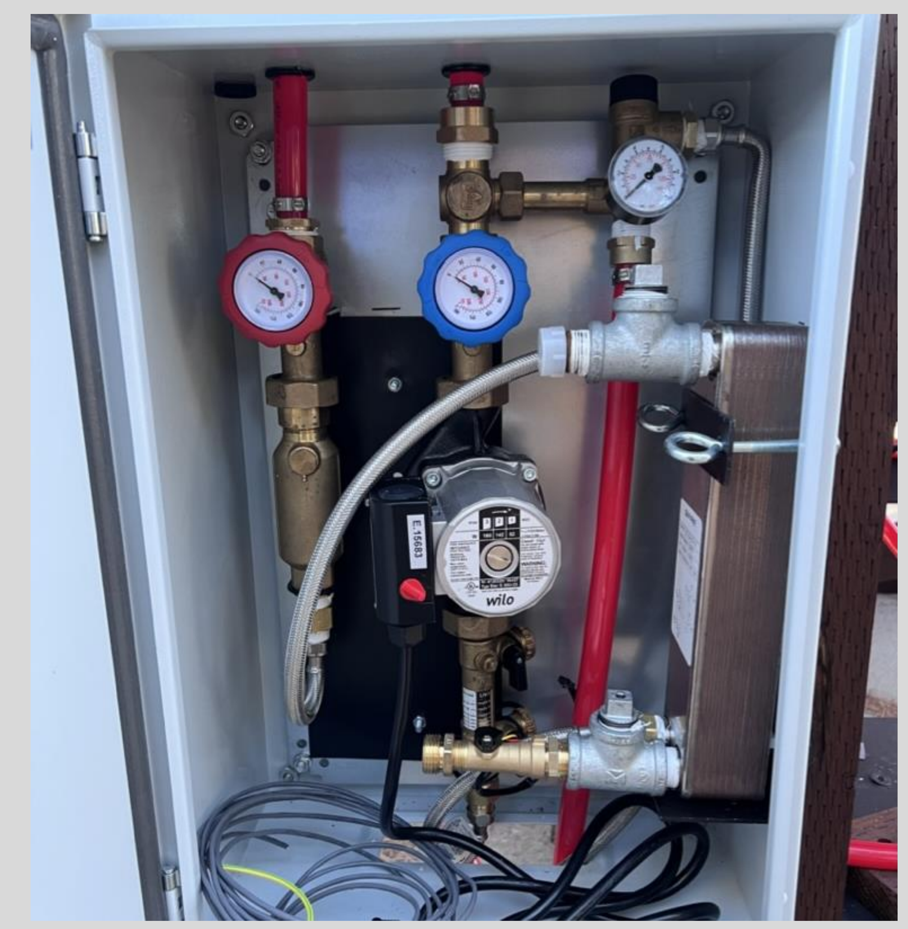

Figure 4: Pump Station and Heat Exchanger for Solar Thermal System

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