Session 2220

Development of an Inexpensive LabView-Based Refrigeration Cycle Laboratory

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Abstract:
A thermodynamic refrigeration cycle laboratory was created using a window air conditioner, pressure and temperature sensors, and a LabView data acquisition system. The system measures the high and low pressures sides and the refrigerant temperatures between the four major components. A National Instrument LabView data acquisition system was used to acquire, transform and present the thermodynamic data to the students over the Internet. The software uses the temperature and pressure measurements to calculate thermodynamic properties such as enthalpy, specific volume and entropy. , These values are used to the calculate specific heat transfers and works of the various components which are then used to estimate the system efficiency.

1. Introduction:

Engineering students taking their first class in Thermodynamics at the undergraduate level commonly fail to relate the theoretical aspects developed in class with the real world. One method of bridging this gap is to integrate a laboratory into undergraduate classes. This is usually expensive and time consuming, especially for classes that have 60-100 students in which multiple lab sections would be necessary. One alternative to traditional laboratories is a remote laboratory that can be accessed through the Internet and broadcast to the students in class or at other scheduled times. This paper presents the development and usage of a remote thermodynamics laboratory. Prior publications have shown that an inexpensive, portable, thermodynamics laboratory is useful [1]; we have taken this one step further and used National Instrument's (NI) LabView (LV) Internet capabilities to bring the laboratory into the class without physically transporting it. A survey of LabView Internet technologies is available [2].

2. Methodology:

An inexpensive, residential, window-type air conditioner was purchased from a local appliance store. Nameplate data is provided in Table 1. The air conditioner was taken to a local refrigeration service provider and fitted with pressure taps on the high and low-pressure sides. Both local gages and pressure transducers were attached to the pressure taps. The local gages were useful in calibrating the pressure transducers. Since the data was used for class related experiments and is not currently used for research, the accuracy of the measurements was not of crucial importance. Thermocouples were then placed between the four major components and the outputs of the instrumentation were connected to a NI SCB-68 connector block. A picture of the system is provided as Figure 1.

Table 1. Air Conditioner Nameplate Data	
Type	Goldstar R5207
Cooling Capacity	5200 BTU/hr
Electrical	115 V, 5 A
Refrigerant	7.8 oz. R-22
Design High Pressure	350 psig
Design Low Pressure	150 psig

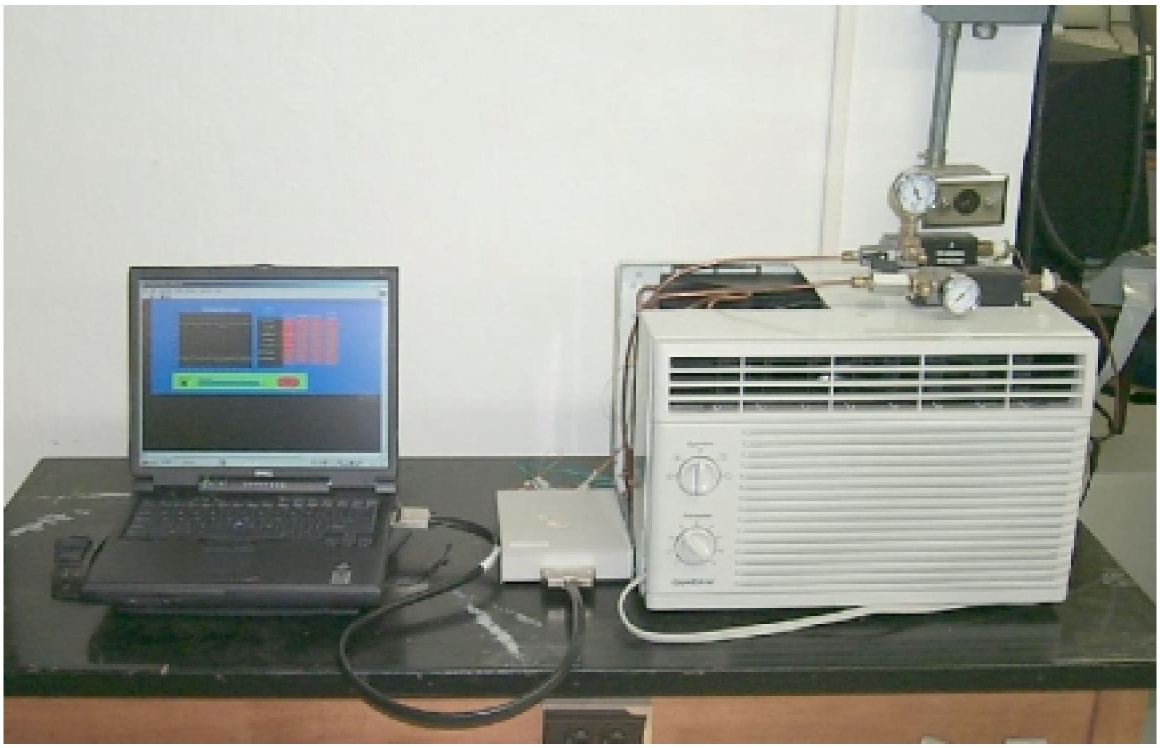

Figure 1. Air conditioner and data acquisition system setup.

A closer view of the instrumentation and components is provided as Figure 2 and mirrors the component setup used in class (Figure 3). Slides are used in class to show the students the various components: compressor, evaporator, condenser, and expansion valve (capillary tube). Pictures of anomalies such as icing during startup are also shown and discussed.

A LabView graphical user interface was developed by two undergraduate students as a summer project. It collects the pressure and thermocouple data, transforms it to normal engineering units, and presents it to future students. This interface is also is served to the web making it accessible to classrooms across campus. Close up pictures and a web cam are used to show the students the operating system while the GUI is used to present thermodynamic data to the students in real time. This setup cost less than $2000 to construct: with an estimated material cost of $500 for the system and sensors, $795 for a LabView starter kit, and $600 for a computer.

Figure 2. Close up of Instrumentation

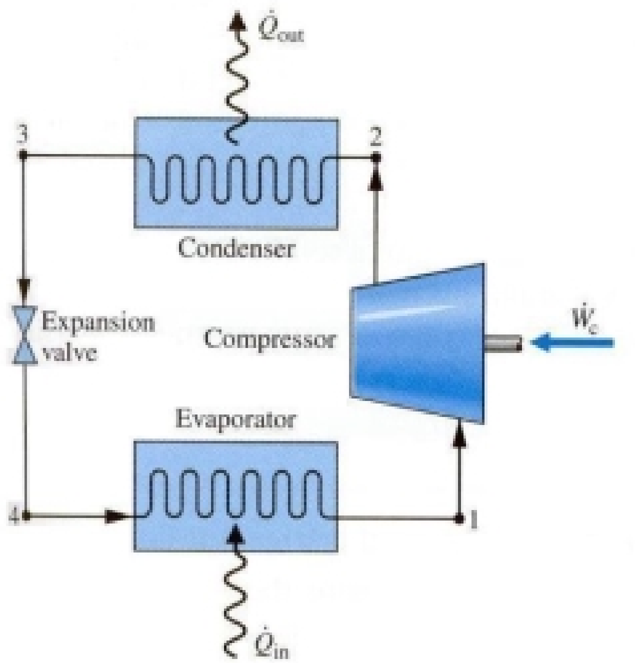

Figure 3. Classroom System Diagram (Reference 3)

The LabView software from National Instruments Company has significantly helped to demonstrate thermodynamics processes and systems, which are fundamental to understanding the basic concepts of thermodynamics, such as the first and second laws of thermodynamics. Due to its practical usage in presenting figuratively the vapor-compression refrigeration cycle and its thermodynamic properties, the system enhances and adds another dimension to the teaching/learning process to the subject of thermodynamics. Students are able to apply thermodynamics principles such as the first and the second laws, and others that they learned in the classroom lectures, to real life applications. This approach makes the subject of thermodynamics a more pleasant experience for the undergraduate engineering students especially that LabView helps to build the experimental setups that can be fully be operated, controlled and monitored remotely using LabView Built-in Web Server.

2. Data Collection and GUI Design:

The design process was theoretically simple where all considerations arising from the formulation of the problem statement, safety, financial, or other concerns were taken into account.

The graphical user interface was designed to display digital values of the four temperatures measured by four thermocouples attached between the four major components of the air conditioner (see Figure 3), additionally, digital reading of the high and a low pressure sides are measured by pressure transducers connected to the tube between the evaporator and the compressor for the low pressure, and the compressor and the condenser for the high pressure. These temperature and pressure readings are used to calculate the basic thermodynamic properties of the system such as enthalpy, entropy, and specific volume. It is assumed that the pressure drop of the evaporator and condenser are negligible, this assumption is common in systems modeled as isentropic. These values are used to calculate specific heat transfers, efficiencies, and could be used to estimate isentropic efficiency of the compressor.

In class students frequently use steam tables and other tables containing thermodynamic properties to specify property values. Performing multiple table interpolations was found to be very difficult in the LabView "G" programming environment. Although single table interpolations were straight forward, interpolating between tables was more difficult. To circumvent this problem, non-linear regression models were calculated to estimate thermodynamic properties given the pressure and temperature of the R-22. This predictive modeling exercise was a useful experience for the undergraduate designers.

Future work with the user interface will include presenting the thermodynamic properties, processes, and cycles in the form of P-v, T-v, and T-s diagrams. This will visually allow the students to recognize works being performed, heats being transferred, and other vital functions of the refrigeration system.

5. Conclusions:

The air conditioner laboratory system described in this paper is a simple, real life application for demonstrating basic thermodynamics processes and principles. The data and GUI is accessible over the web, which allows the system to be used for at home laboratory experiments and classroom demonstrations. It was fairly inexpensive, as compared to $25,000 thermodynamic systems sold as refrigeration technician trainers, but a very valuable addition to the undergraduate engineering experience. Future work using this laboratory will include assignments using the data collected from the air conditioner, extra credit projects to expand its use, and additional thermodynamic demonstrations including transients.

Bibliography:

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