DATA ACQUISITION AND ANALYSIS IN A HEATING, VENTILATING AND AIR CONDITIONING LABORATORY USING SOFTWARE SYSTEMS

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Introduction

Data acquisition and analysis demonstrates the use of software to students linking the somewhat abstract software programs with experimental data.

The acquisition and analysis approach used in Heating, Ventilating and Air Conditioning Design (HVAC) - a junior/senior level course for Mechanical Engineering Technology students - has evolved over a period of years. The sequence of topics covered in the laboratory along with the equipment, instrumentation and software tools are discussed in the following sections.

Laboratory Topics

Students entering the HVAC course have completed thermodynamics, a sequence of mathematics courses through calculus, a programming language course and have varied levels of experience/exposure to software systems.

The HVAC laboratory is premised on minimal student software expertise and approximately one-third of the laboratory is devoted to the use of data acquisition and analysis tools and design software. The remainder of the course covers transducer calibration and heating, ventilating and air conditioning experiments with the data acquired and analyzed using the software systems covered in the first third of the course. The HVAC measurements consist of temperatures and pressures. These parameters are measured using thermocouples and pressure transducers. The analog signals are digitized and displayed using the Labtech Notebook software system [1, 2].

The data analysis tools consist of QPRO [3], FREON [4], PsyChart [5] and GRAFPLUS [6]. QPRO is used for general computations, statistical analysis and chart and graph generation. FREON supplies thermodynamic properties for refrigerants and PsyChart is used to define wet air state points and wet air processes, i.e., heating, humidification, dehumidification, mixing, etc.

The design programs utilized in the laboratory are RHVAC [7] and DUCTSIZING [8]. RHVAC determines residential and commercial HVAC loads given various building parameters. DUCTSIZING determines optimal duct sizes given volumetric flowrates, desired noise levels, etc.

The laboratory experiments utilize all the data acquisition and analysis software and are discussed in the following sections.

Air Conditioning Laboratory Unit

The HVAC air conditioning laboratory unit [9] is shown in Figure 1. The unit demonstrates all the basic HVAC functions, i.e., humidification, heating, dehumidification of wet air. The unit utilizes an R- 12 refrigeration system. Heating, humidification and volume flowrate can be independently controlled. The refrigeration system operates at a fixed point although the refrigerant temperatures, pressures and mass flowrate fluctuate slightly with the evaporator load.

The unit instrumentation is shown in Figure 1. T1, T2, T3, etc. denote thermocouples. P1 and P2 are pressure transducers with DP being a differential pressure transducer. The air flow analysis stations are identified as **A**, **B**, **C**, and **D** with the refrigerant stations as ①, ②,③ and ④. The refrigeration measurement points are linked to the system components. T_7 and P_1 correspond to the compressor inlet, T_9 and P_2 to the condenser exit and T_8 to the evaporator inlet.

Data Acquisition

All data from the air conditioning laboratory unit except the refrigerant flowrate is acquired using Labtech Notebook and Omega Engineering plug-in-boards [10]. The temperatures and pressures are displayed in both analog and digital form.

The thermal stability and/or equilibrium is determined from the analog display - variability of temperatures and pressures with time. The numeric values are stored and at the completion of the experiment are analyzed using QPRO. A typical spreadsheet is shown in Figure 2. This data was logged on a 60 sec basis and only one of the time points is meaningful - the remaining points which were acquired to establish thermal stability are discarded.

Data Analysis

The data of Figure 2 are analyzed using PsyChart, FREON, and QPRO. One time point from Figure 2 coupled with the orifice flowrate equation provides a complete description of the wet air system.

The wet-bulb and dry-bulb temperatures, e.g., T1 and T2, define a wet air state point. Two state points along with the mass flowrate define a process. The processes define the various heating rates or loads. PsyChart uses the wet- and dry-bulb temperatures to define state points and processes. A typical state point, process graph is shown in Figure 3. The state points and processes were developed with PsyChart with the graph produced by AutoCad Lt[11].

The refrigeration system analysis is based on measured temperatures, pressures and the refrigerant flowrate. The thermodynamic properties corresponding to the measured values are determined using FREON. A screen display - captured with GRAFPLUS - is shown in Figure 5.

While the wet air processes can be analyzed using PsyChart, FREON provides only thermodynamic properties. The cycle analysis is carried out using QPRO. As can be seen from Figure 1, the refrigeration system measurements are limited to a temperature and a pressure at the compressor inlet, a temperature and a pressure at the condenser exit, a temperature at the expansion valve exit and the refrigerant flowrate. In essence, data is available at stations ①, ③and ④. As a consequence, assumptions must be made about the processes ①→②, ②→③ and ④→①. The condenser and evaporator processes, i.e., ②→③ and ④→①, are assumed to occur at constant pressure and the compression processes, i.e., ①→②, is assumed to be isentropic. The processes and state points for the refrigeration cycle are shown in Figure 5.

Summary

The HVAC laboratory course provides a comprehensive experience for students in the use of software systems. The systems range from data acquisition through data analysis to system design. The use of software in a laboratory environment with actual measurements provides a sense of realism that is sometimes lacking in design exercises.

References

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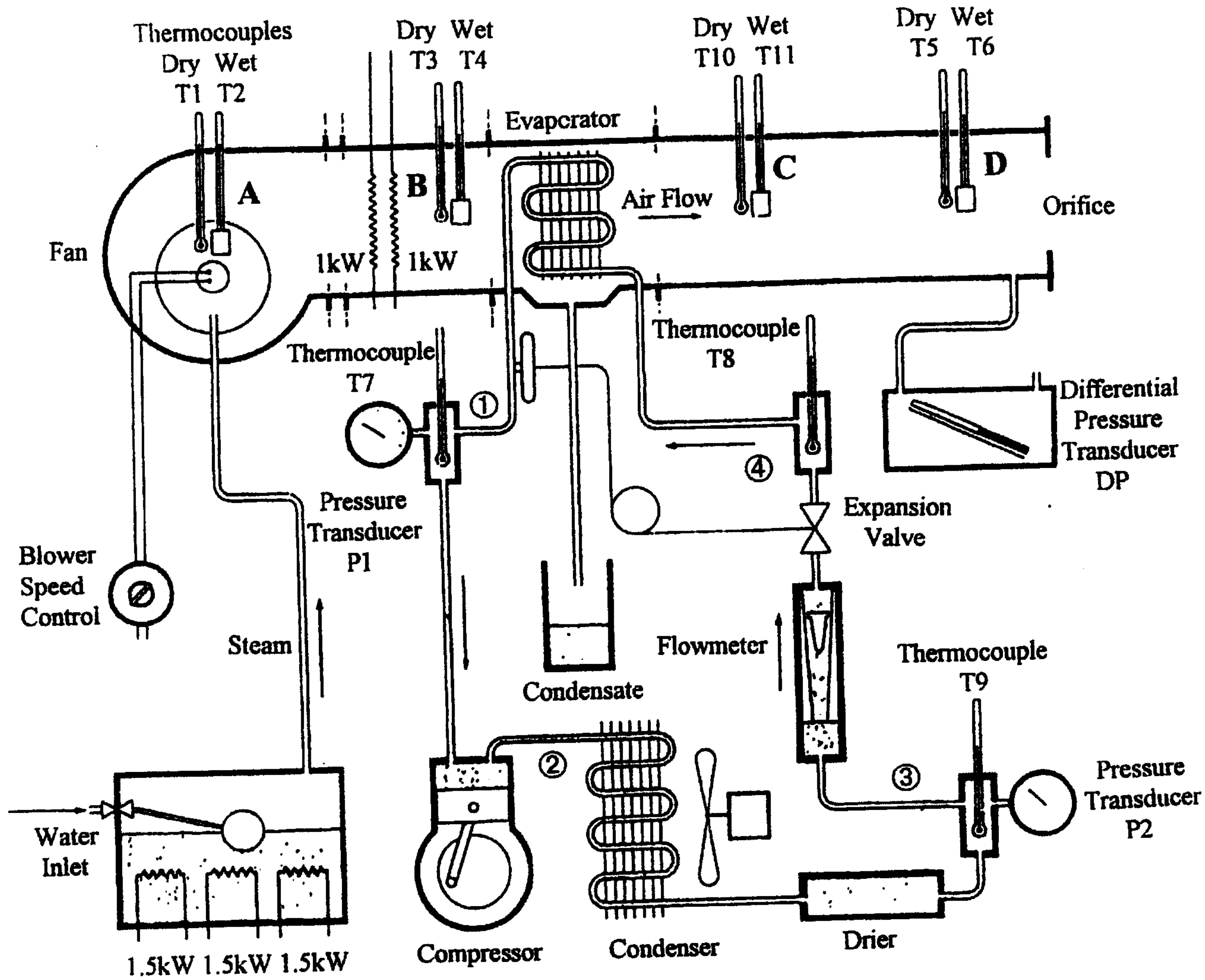

Figure 1. Air Conditioning Laboratory Unit

Time Sec	T1 DegF	T2 DegF	T3 DegF	T4 DegF	T5 DegF	T6 DegF	T7 DegF	T8 DegF	T9 DegF	T10 DegF	T11 DegF	PI PSIG	P2 PSIG	DP mmH20
0	72.5	62.2	94.3	76.5	86.3	68.9	60.5	56.6	111.2	86.3	68.9	49.8	133.8	8.3
30	72.2	62.2	94.0	77.3	86.0	68.8	60.4	56.3	111.5	86.1	68.7	49.0	134.6	8.4
60	71.9	61.7	93.8	78.4	85.7	68.4	59.8	56.0	111.2	86.0	68.7	49.0	134.6	8.3
90	71.7	61.6	93.6	79.6	85.9	68.2	59.8	55.8	111.2	86.1	69.0	49.2	134.9	8.4
120	71.7 .	61.4	93.5	80.6	85.6	68.0	59.4	55.5	111.2	85.7	69.1	49.2	135.3	8.2
150	71.5	61.4	93.1	81.5	85.1	67.7	59.1	55.2	111.2	85.5	68.4	48.9	135.6	8,3
180	70.9	60.7	93.0	82.8	84.9	67.6	58.9	55.0	111.1	85.3	68.6	49.2	135.6	8.1
210	71.1	60.9	92.8	83.9	85.0	67.6	58.5	54.8	111.1	85.2	68.8	48.8	135.6	8.0
240	71.3	60.8	92.6	85.0	84.3	67.2	58.4	54.5	111.1	85.3	68.9	48.9	136.7	8.2
270	70.8	60.4	92.1	84.2	84.1	67.1	58.0	54.3	111.1	84.9	67.7	48.8	136.3	8.0
300	70.4	61.8	90.6	80.8	84.1	66.7	57.9	54.1	110.9	84.9	66.3	48.9	137.1	8.0
330	70.4	60.7	89.9	78.9	84.2	66.5	57.7	53.9	111.0	84.7	65.7	48.8	137.4	8.1
360	70.1	60.2	89.7	77.6	83.9	66.4	57.3	53.5	110.5	84.6	65.7	48.9	137.4	8.0
390	70.1	59.9	89.9	77.4	84.1	66.1	57.3	53.4	110.9	84.3	65.3	48.8	138.1	8.1
420	69.9	59.7	89.7	77.1	83.7	65.8	56.9	53.2	110.7	84.3	65.5	49.4	138.1	7.9
450	70.1	59.4	89.6	77.4	83.7	65.8	56,9	52.9	110.7	84.3	65.2	49.0	138.1	7.9
480	69.8	59.3	89.5	77.9	83.5	65.6	56.5	52.8	110.8	83.9	65.0	48.5	138.8	8.1
510	69.3	58.8	89.4	78.2	83.3	65.5	56.1	52.4	110.7	83.9	65.0	48.6	138.8	8.1
540	69.0	58.6	89.5	78.9	83.0	65.3	56.1	52.2	110.7	83.8	64.9	48.5	139.2	8.0
570	68.8	58.5	89.3	79.1	82.9	65.2	55.5	51.9	110.6	83.4	65.0	48.6	139.6	7.8
600	68.5	58.1	89.0	79.5	82.6	64.9	55.4	51.8	110.7	83.1	64.4	48.6	139.2	8.0

Figure 2. Labtech Notebook Data Output

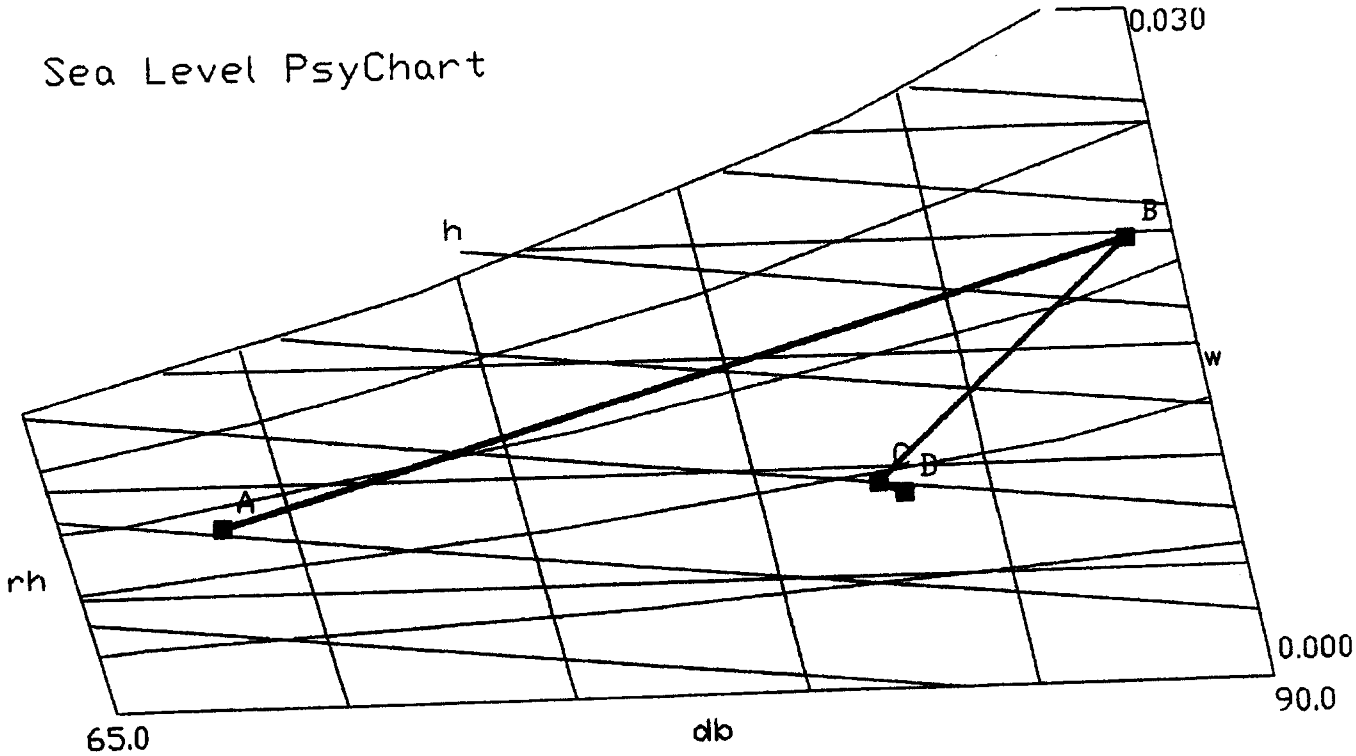

Figure 3. State Points and Processes from PsyChart

R-12 - Dichlorodifluoromethane - CCl2F2			
P R O P E R T Y	Dimension	INPUT VALUE	CALCULATED
Temperature	Fahrenheit	55.40000	55.40000
Pressure	Pounds/inch**2	63.30000	63.30000
Specific Volume	Foot**3/pound		0.64303
Enthalpy	Btu/lbm		83.19400
Entropy	Btu/(lbm*deg F)		0.16633
Quality	Dimensionless		SUPERHEATED

Figure 4. Refrigerant Properties from FREON

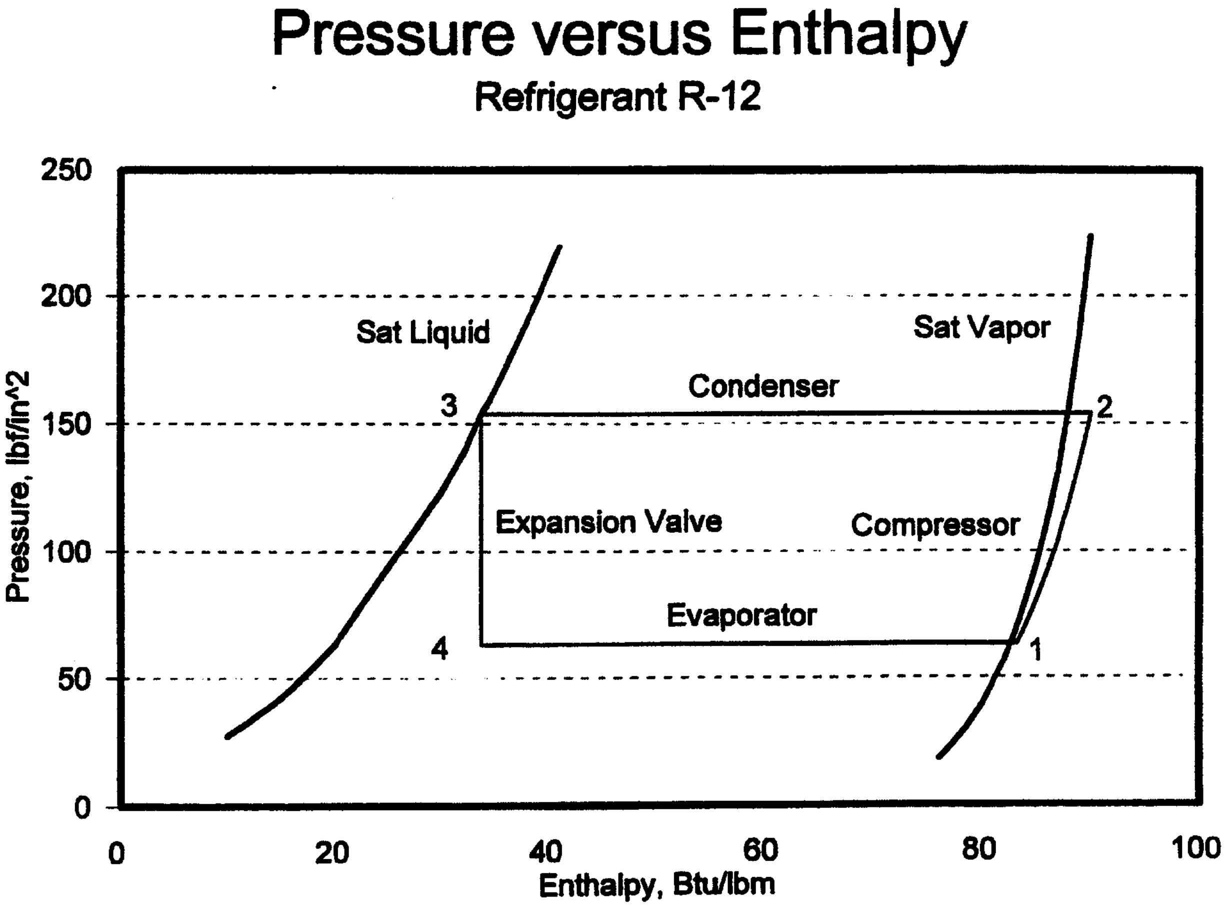

Figure 5. A Typical Refrigeration Cycle

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