DEMONSTRATIONS AND CAMPUS FACILITIES FIELD TRIPS FOR A HEATING, VENTILATION AND AIR CONDITIONING COURSE

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ABSTRACT

This paper will describe a set of class room demonstrations and on campus field trips that have been developed to supplement the class room lectures in the heating, ventilation and air conditioning (HVAC) course. The value of these demonstrations and field trips is to provide the students with an enhanced understanding of the design control and operation of HVAC equipment and then to mathematically model this equipment for the performance of perform various types of analysis such as thermodynamic processes and cycles, liquid and air flow for pumping and fan power, heat exchanger siring and performance and thermodynamic and psychometrics.

1. Introduction

The Heating Ventilation and Air Conditioning (HVAC) course at Union College is generally taken by seniors in the Mechanical Engineering and it represents an application of the principles they have learned in earlier thermodynamics, heat transfer and fluids.

The objective of the course is first to teach how existing HVAC systems work and then to define possibilities to make systems more energy efficient via the options of decreasing demand or increasing the efficiency of the supply or by better computer based control.

The author has been teaching this course for four years which had previously been totally instructed by lecture. A formal laboratory could have enhanced the educational process but time and funds did not exist.

Thus the instructor has developed a combination of HVAC class room demonstrations and campus field trips in lieu of a formal laboratory.

The first class room demonstration is operating and measuring the pressures, temperatures and flow rates on an instrumented window type air conditioner and from these measurements analyze the cycle, heat exchangers and electric power requirement. Subsequent class room demonstrations are measuring dry and wet bulb temperatures as an introduction to psychometric analysis and measuring the performance of a Peltier effect cooler that is used in automobiles.

A field trip is taken to our adjacent physical facilities building where the operation of the central chillers, evaporative cooling towers and central heating boilers are observed along with the central computer that monitors and controls the temperatures of the buildings throughout the campus.

Another field trip is taken to the ice rink in which chillers are observed and analyzed along with the chilled brine loop between the evaporator and rink floor.

Another trip is to see an air conditioner that combines desiccant drying and evaporative cooling and that was designed by a student for a senior project.

This paper will further describe these demonstrations and on campus field trips and the subsequent student reports and comments that demonstrate the effectiveness of these demonstrations and visits to the campus physical facilities.

2. Description

This section will describe the various demonstrations and field trips, and corresponding analysis performed on the equipment.

WINDOW AIR CONDITIONER

A 6,000 Btu hr window type air conditioner using freon 22 is instrumented for flow rate, high and low side pressures and temperatures at each point as shown in Figure 1. This air conditioner is instrumented to measure freon flow rate (lbm/hr), temperatures at each point (F) and high and low side pressures.

Figure 1 Instrumented Window Air Conditioner

A cycle diagram is then constructed of a pressure vs enthalpy thermophysical properties chart for freon **22.** A corresponding property table is constructed for the points corresponding to compressor inlet, compressor discharge, desuperheater exit, condenser exit, and throttle exit showing the pressure, temperature, specific volume, enthalpy, mixture and entropy at each point. A 1st Law process and cycle table is then constructed for the compressor, desuperheater, condenser, throttle and evaporator showing rate of heat transfer, rate of freon stream energy change and power (Btu/hr) for each process and for the full cycle. The isentropic efficiency of the compressor and the coefficient of performance is also calculated.

Next a heat exchanger analysis is performed to obtain the overall heat transfer coefficient (Btu/hr F) for the evaporator, desuperheater and condenser, and improvement of coefficient of performance that could result from improving these heat exchangers is considered.

Modem electric driven air conditioning and refrigeration with freon as the working fluid is one of the most important new technologies of the century, and the hermetically sealed canned electric motor/ compressor is a vital component. Accordingly, we cut open a compressor with a hack saw to examine the internal design as shown in Figure 2.

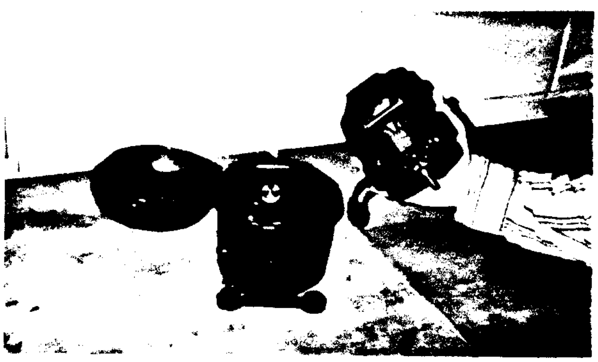

Figure 2 Cut Open Hermetically Sealed or Canned Motor/Compressor

ELECTRIC POWER MEASUREMENT AND EQUIPMENT CONTROL

An standard residential type AC electric power meter is mounted in the electric supply circuit to directly measure electric power and energy consumption for air conditioners or refrigerators as shown in Figure 3.

Devices such as air conditioners, refrigerators and furnaces are typically controlled by ON/OFF thermostats, and a demonstration control circuit has been constructed and is also shown in Figure 3.

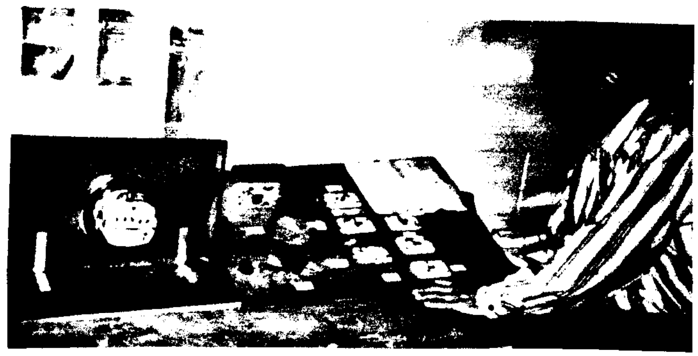

Figure 3 Electric Power Meter and Controller

CENTRAL COMPUTER BASED HVAC CONTROL

Temperatures and ventilation rates in the various buildings on campus are centrally controlled via a programmable central computer that also monitors conditions in the various zones of the buildings. Measurements from the building are temperatures and valve and damper positions, while signals to the buildings open and close valves and dampers to regulate the actual temperatures at the set point levels. This central computer control is demonstrated as shown is Figure 4.

Figure 4 Central Process Computer for Controlling Campus

CENTRAL BOILERS

Heat for the buildings is supplied by two 40,000 lb/hr water tube boilers with dual fuel options between natural gas or residual oil. These boilers are examined along with the windbox and control linkages for drum water level, pressure and fuel to air ratio. A decrease of pressure relative to the set point pressure results in a signal to a motor controller that simultaneously opens a fuel valve and air flow damper as shown in Figure 5.

Figure 5 Burners, Windbox and Control Drive Shaft for Boiler

A control panel provides the operator interface for programming boiler pressure and stack oxygen level as demonstrated in Figure 6.

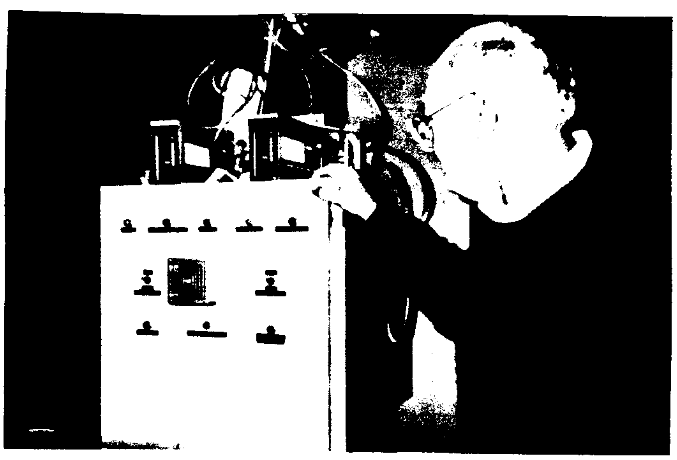

Figure 6 Boiler Control Panel

COGENERATION

Cogeneration means using the same fuel to produce mechanical or electrical power and useful heat and has the potential of saving fuel and decreasing total electric and fuel costs.

A cogeneration topping cycle has been installed that can produce about 500 kw from a turbine/genemtor using boiler steam at about 150 psia with exhaust steam at 30 psia as shown in Figure 7.

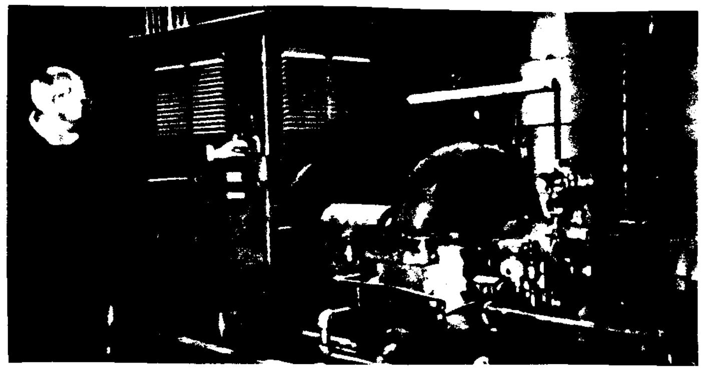

Figure 7 Cogeneration Turbine/Generator

This unit is demonstrated and students calculate fuel and cost savings as a function of fuel costs and electric utility rates.

CENTRAL CHILLERS

Two 300 ton electric compression chillers as shown in Figure 8 are installed. The evaporators provide the chilled water for campus buildings, and the condensers are cooled with water from the cooling towers.

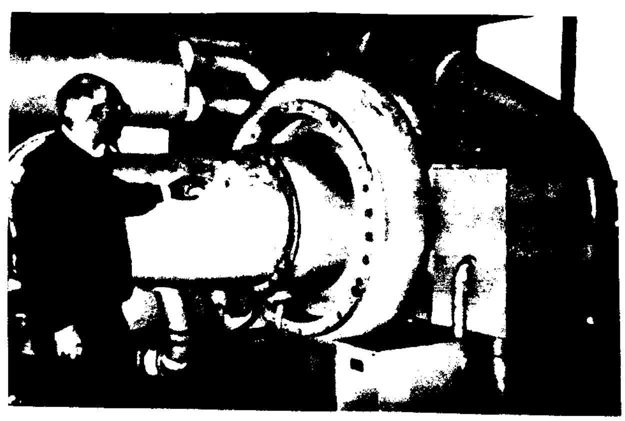

Figure 8 Central 300 Ton Chiller

These chillers have two stage compressors with an intercooler and inlet guide vanes that allow reduced output operation without wasteful throttling losses. These central chillers are examined and analyzed in terms of the thermodynamic cycle, control and heat exchanger performance.

Large vertical shaft electric driven vertical shaft circulating pumps are installed in the chilled water loop and in the cooling tower loop as shown in Figure 9. Electric power requirements are calculated for these pumps on the basis of flow rates and pressure head.

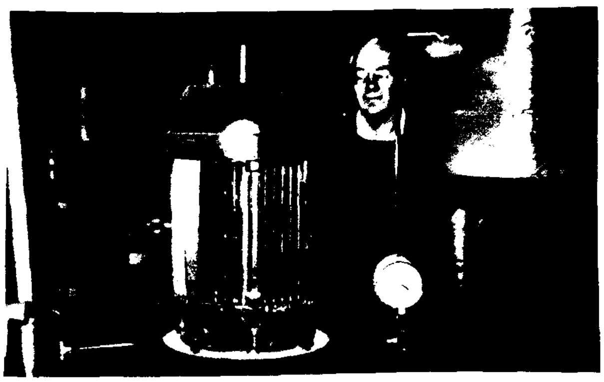

Figure 9 Chilled Water Circulating Pumps

The field trip proceed outside to observe the design of the evaporative cooling towers as shown in Figure 10.

Figure 10 Outside of Cooling Tower Looking Up

We then climb inside the inner chamber of the cooling tower to observe the honey comb side walls in which the incoming air evaporatively cools the falling water, the lower chilled water reservoir, makeup water line with controller and the vertical shaft exhaust fan on the top as shown in Figure 11.

Figure 11 Inside Cooling Tower

We then climb on the top the cooling tower to observe the return flow of the heated water from the chiller condenser as shown in Figure 12, and then analyze the performance using psychometric analysis to calculate the amount of required makeup water and temperature drop of the cooling water as a function of heat load.

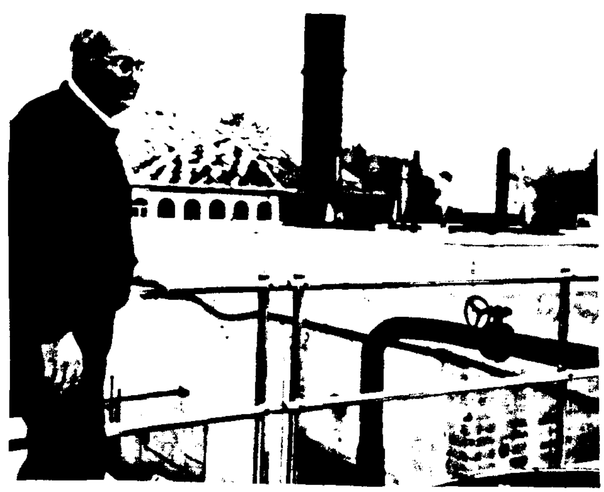

Figure 12 Top of Cooling Tower and Ice Rink in Background

ICE RINK CHILLERS

The domed building in the background of Figure 12 is the ice rink that is now analyzed starting with the skid mounted compressors and chilled water producing evaporators that are shown in Figure 13.

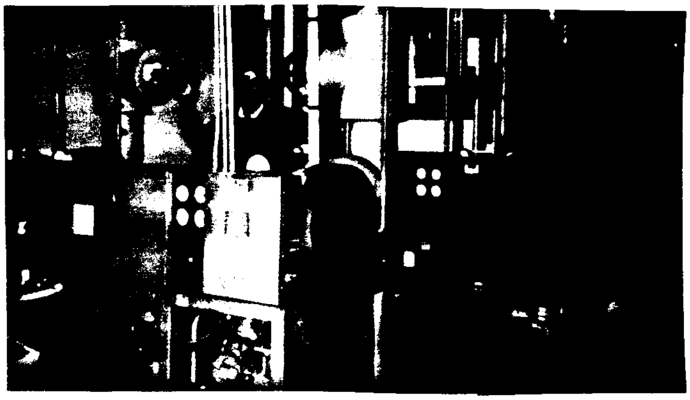

Figure 13 Ice Rink Chiller Skid with Compressor and Evaporator

The chiller system utilizes heat exchangers to recover the high temperature heat from desuperheating freon for building hot water as shown in Figure 14

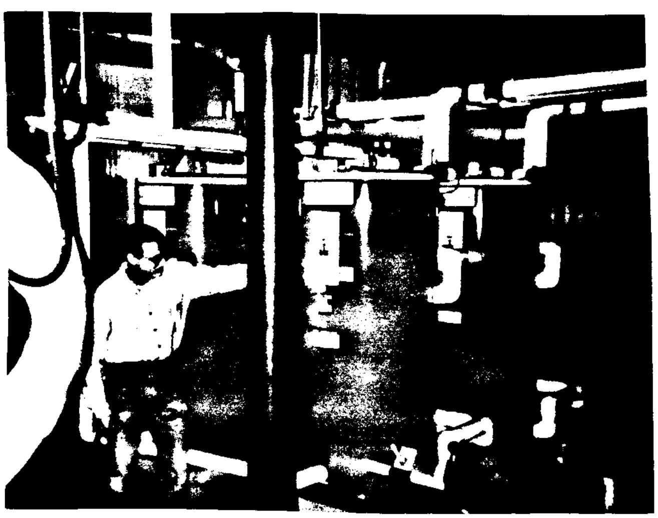

Figure 14 Heat Recovery from Desuperheating Freon

The freon is then condensed outside the ice rink building by air cooled condensers as shown in Figure 15.

Figure 15 Outside Air Cooled Freon Condensers

Students are then asked to perform the analysis of the ice rink refrigeration system as part of the third exam in the course.

An alternative air conditioning system is a combination desiccant and evaporative system shown in Figure 16 that a prior student had designed and built at a senior project (Reference 1).

Figure 16 Combination Desiccant/Evaporative Air Conditioner

Analysis of this system requires measurement of the dry and wet bulb temperatures in the ducts as the first step in the psychometric analysis as shown in Figure 17.

Figure 17 Wet and Dry Bulb Temperature for Psychometric Analysis

Students then calculate the amount of cooling performed, the amount of water required for evaporation and the amount of heat required for desiccant drying.

PELTIER EFFECT COOLERS

An alternative method for cooling is the use of a Peltier effect based system that is similar to a thermocouple effect operating in reverse. Such devices are available as automobile coolers and are powered by 12 volt DC via the cigarette lighter. One of these coolers is procured, dismantled as shown in Figure 18 and reassembled and then tested in terms of power requirements and coefficient of performance.

Figure 18 Reverse Engineering and Analysis of Peltier Cooler

The cooler box insulation heat loss performance (watts/C) is also measured by measuring the rate of ice melting and corresponding inside and outside temperatures.

An earlier student performed a detailed parametric analysis of a Peltier cooler to determine what improvements would be required to make such a system competitive with a conventional electric compression cycles (Reference 2).

ELECTRICITY PRODUCING CONDENSING FURNACE

The electricity producing condensing furnace (EPCF) is a concept that combines the fuel saving techniques of a natural gas fueled gas hot air condensing furnace with the fuel saving technique of cogeneration. Such a system is comprised of burning the fuel in a single cylinder air cooled engine and a grid induction motor/generator as shown in Figure 19.

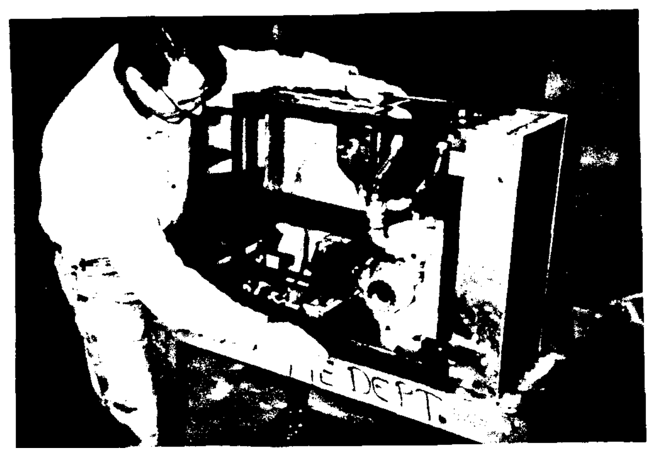

Figure 19 Student Constructed Prototype of an Electricity Producing Condensing Furnace

Prior students have built operating prototype of an EPCF and the results of these projects have been published and presented (Reference 3) and this prototype is used to demonstrate the design and thermodynamic principles of this system to each HVAC class.

3. Conclusions

The author believes and the student evaluations have steadily confirmed that the field trips and demonstrations and the resulting types of analysis that has been described in this paper very much enhances the understanding of HVAC systems relative to a lecture only format.

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References:

1. Frank Wicks and Tim Griffin, ‘Design and Performance Evaluation of a Residential Size Peltier Effect Refrigerator”, Presented and Published in the Intersociety Energy Conversion Engineering Conference and Proceedings, Vol 1, pp 1039-1046, August 1993, Atlanta.

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3. Frank Wicks, ‘Design and Performance Evaluation of a Residential Size Peltier Effect Refrigerator”, Presented and Published in the Intersociety Energy Conversion Engineering Conference and Proceedings, Vol 1, pp 1039-1046, August 1993, Atlanta.

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