2002-147 - ALTERNATIVE WAYS TO TEACH HVAC AND RELATED SUBJECTS THROUGH ACTUAL PROJECT INVOLVEMENT -THREE CASE STUDIES

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At UNLV two courses in HVAC design are taught on a regular basis. These courses also attract students who are interested in the subject and in some cases may have some previous experience to continue in that general area by taking these two courses as an elective which can count towards their undergraduate degree or as part of their course fulfillment towards a Masters Degree. When the student has had some exposure to the subject matter it becomes a little bit more challenging to present them with a situation that can be satisfying for them. This paper presents three cases regarding studies of typical projects that somewhat more experienced students were involved in to satisfy part of their degree requirement. The first one was an actual "consulting job" on campus that the student was involved in to perform an indoor air quality study at the Hotel College building at UNLV. The second one was a job to perform an independent senior undergraduate study on the comparison of lifecycle costs of two HVAC systems that were of interest to the office of Rehabilitation/ Facilities/Planning department for the local County School District. The third case is an ongoing project where UNLV along with the local electric utility company have formed an Energy Assessment Center (EAC) to address the needs and concerns of customers who want to reduce the peak energy demand and try to qualify for a rebate from the power company.

It was found that these projects can be handled by the students and were of special interest to them in giving a hands-on- experience when dealing with an everyday technical problem.

These three projects have been found to present invaluable learning tools to the students outside the classroom and where the feedback from the students is to try to have more of these types of studies.

INTRODUCTION

HVAC education has seen a certain amount of shrinkage of interest in the Mechanical Engineering curricula in today's US universities. The study of this subject is more and more relegated to the more specialized departments of Architectural Engineering it seems. Even these programs are in very limited supply in the US as probably fewer than ten or less are available for undergraduate study. At the University of Nevada Las Vegas(UNLV) and due to its geographic location and extreme climatological conditions in the summertime the need to teach HVAC design courses has been moving on a reasonable keel. Two technical elective courses in HVAC are offered for the undergraduate or beginning graduate students in ME. These courses are mainly designed to expose the students to some of the design calculations that need to be undertaken for a feasible cooling or heat load calculation. As part of the coursework all students are required to complete a relevant design project for a detached house. The students signing up for the course as graduate students are required also to complete to review of a research paper from the recent ASHRAE review literature and as part of the deliverable a final written report is due as well as a 15-20 min. oral presentation is to be made by each of the students at the end of the semester. The first of these two courses MEG418/618 involves the introduction of the psychrometric charts and their basis, the various calculations of the U-factors along with a review of some basic notions in the three modes of heat transfer, wind load calculations, heating load calculations, cooling load calculations, piping/pump considerations and terminal air diffuser distribution and selection. The second course MEG419/619 describes the air distribution/fan selection and duct design, direct contact heat exchangers, indirect heat exchanger selection methods, refrigerant side thermodynamic considerations and finally an introduction to solar heat gain calculations including the different ASHRAE Clear Sky models etc…

A partial survey of the literature concerning previously reported published effort on the teaching of HVAC has been made using the COMPENDEX online database for the last ten years. In his paper Alexander, R.C. (1990), has suggested that faculty teaching HVAC courses should also be grounded in the design aspect of the technology not just in the research part as usually maybe the case in academia. Meredith, D. (1990) and Fung A.S. have presented some BASIC language design programs and a computer-controlled laboratory air conditioning units respectively to teach HVAC courses. Walton A. et. al. (1996) discussed the development of three laboratory experiments to teach HVAC principles. Santos J.J. (2001) emphasized controls education for HVAC design engineers. Some researchers like Stevens J.W. (1997) emphasized desiccant instruction in HVAC courses, others like Oppenheim P. (1994) emphasized introduction of the environmental technology component in the curriculum of building construction programs. The next two references were closer to real world HVAC applications, the first of which Chen C.C. (1993) involved direct participation of undergraduate students in energy audits for commercial customers and the last by Nasr K. (1998) involved performing several experiments on a donated vehicle which include one for the HVAC unit. A fairly recent paper has been published recently by Forsberg C. (2001) on the use of computers in HVAC education. Unfortunately the author has not been able yet to obtain more information on the paper for comparison.

The approach reported in this paper is complimentary to some of the above mentioned and can be categorized as one where more real world applications are involved.

CASE STUDIES

I would like to mention here that the three case studies to be discussed here were not part of one course designed strictly for HVAC but grew from some requirements of having to solve practical problems in the field or answer some design options that did not have a direct answer but needed to be analyzed. However having defined these problems it was felt that the answers to these problems are worthwhile cases to be incorporated as a graduate project in one case, an independent study in the other two cases.

CASE I

Definition:

To propose recommendations to assist in alleviating the odor diffusion from the kitchen area at the second floor north area of Beam Hall on the campus of the University of Nevada Las Vegas (UNLV), to adjacent areas. The study of air quality is not the objective but is a related issue. Only an evaluation of existing duct work installation and design conditions will be addressed.

Discussion:

Frank and Estelle Beam Hall is the location at UNLV of the Hotel and Business Colleges. As such there are kitchen facilities that serve as teaching laboratories for the students of the Hotel Management College. Previous studies were made on the issue before and found some irregularities in maintenance and minor design problems. Apparently whatever was suggested as remedies before did not correct the problem adequately and the problem persisted. Although it has to be mentioned here that previous studies did ascertain that in all the affected spaces though the levels of TVOC, CO2,CO,bacterial/fungal levels and organic solvent and ionizable gas levels were within acceptable limits and standards. The above mentioned building is composed of two floors which are served by five major air handling units and a multitude of exhaust fans and hoods. The return air is returned to the units via a plenum a return fan is also used to circulate that return back to the main equipment room on the second floor. The air handling unit of interest is named AHU-4 which serves the lab kitchens and the banquet room. Also in the kitchen areas there were several fresh air make up units using an evaporative cooler to condition the incoming air. The air from the two kitchens is usually exhausted from the space by the use of exhaust fans on the roof of the two story structure. Figure 1 shows a very approximate schematic layout of the three rooms of concern. These is a teaching kitchen facility (lab kitchen-Rm 234) ,the production kitchen-Rm 230 and the banquet room- Rm 233. The production kitchen is designed to actually cook meals in mass to be served in the banquet facility to give the students the feel of a real restaurant. The Hotel College actually holds several luncheons every semester which are designed and executed by the students under the guidance of an instructor as part of a course. One thing that is not presented in this figure and obviously does exist in the actual drawings is the existence of entryways through all the partition walls shown in this drawing. Hence there is connectivity of these spaces to each other. Due to the fact that the drawings for this building were fairly old no CAD versions were available for the student to look at. We had to work off the actual blueprints and those in turn had several changes marked on them in a free hand drawing style. It is noted that with a generic survey of the area of concern it was found that several hardware items that were installed were not even marked down on these drawings which made things a little bit more hectic to track down. Unfortunately downsizing the drawings to a level to be included in our paper would have made their clarity questionable for presentation anyway as they came off

sheets that are about 3.5 by 2.5 ft. or more in size. In any case the presentation of these case studies is not so much to convey in great detail the technical content of the problem as opposed to conveying a sense of what the student had to go through to try to resolve the problem in a somewhat methodical way.
To start out the study the student performed a simple pressurization test between the production kitchen 230 and the banquet area 233 to see under normal operation of the different fans and air conditioning units if there is negative/positive pressure difference created between the banquet hall and the production kitchen. This approach used an inclined manometer capable of measuring to the order of 0.01 inches of water. The result was found to yield a net negative pressure between the kitchen and the banquet hall. So obviously this mode of running could not explain odor dispersion in other areas besides the kitchen. Using the concept of a mass balance around a control volume in the field can give an idea of whether the space is negatively or positively charged. This is depicted in figure 2. Where supply air SA can be considered as the sum of return air RA and exhaust air EA. Also supply air is equal return air plus outside make air, OA. Which theoretically will give the result that OA equals EA. But more often than not the imbalance between OA and EA is the cause of positive and negative pressurization, i.e. OA>EA positive pressurization and OA<EA negative pressurization in the space occurs.

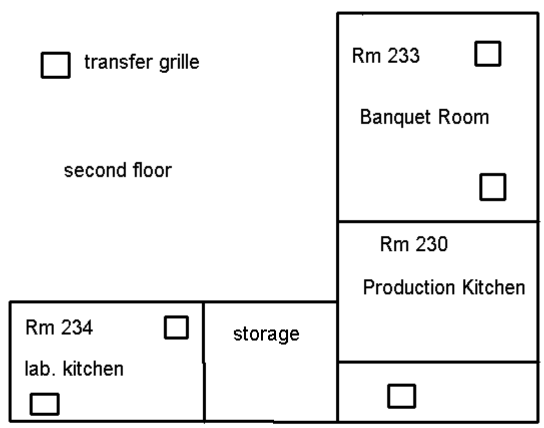

Figure 1. Layout of Kitchen and Banquet Areas

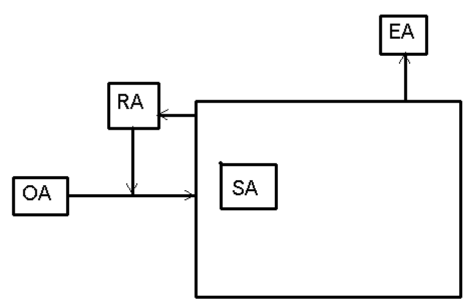

Figure 2. Diagram of Air Flow Around Control Volume

An air balance was made according to figure two for the Lab. kitchen based on values of the exhaust fans and the make up air unit serving that space. It was found that the exhausted air is less by about 100 CFM than the outside makeup air. Although this is not a large value compared to the average air volume of the incoming air i.e. 16900 CFM (cubic feet per minute), but it does indicate that a tendency for the air in that space to be positively pressurized and hence allowing a potential for the room air to drift into the common return plenum and mix with the supply air for other air handling units serving the second floor. Another air balance is made for the banquet room (Rm 233) which indicated that according to the selected values of the CFM for the two units serving this space i.e. an exhaust fan and an air handling unit where the net difference between the supply and the exhausted air is –2400CFM which indicates that this space in under negative pressure according to the design values of the equipment as mentioned on the plans. But since this is a teaching laboratory and the exhaust fan of 3600CFM is turned off sometimes after class adjourns then the supply from the air handling unit could positively pressurize that space and lead to odors going up into the return plenum hence contaminating supply air for other areas on the second floor. Again a reminder here that the return to all the air handling units for both the first and second floor share a common return.

The air balance on room 230 i.e. production kitchen is completed with all the units servicing that space being operational yields at least according to drawings about +250CFM i.e. OA>EA i.e. positive pressurization and could explain in part some of the problems. Had the exhaust fan in the adjacent space (233) been energized though this would have rendered the kitchen space with a negative air balance and might have solved the problem. The exhaust fan in question is rated at 2460CFM. In fact it needs to be mentioned here that after initially surveying that building it was revisited about two months later when it was found that a new packaged 20 ton air conditioning unit was installed over the banquet and production kitchen with no prior notification. That unit supplies about 8000 CFM and returns 6000CFM with a fresh air capacity of 2000CFM supposedly to improve the cooling in the kitchen area. This new A/C unit replaced one of the makeup air units over that space which providing a 6600CFM of air inside the space. With the removal of that unit the net outside air was reduced due to this A/C unit by 4600CFM which made the net air balance of the combined space 230 and 233 have a negative value i.e. negative pressurization of about –6810CFM when the assumption is made that all the exhaust fans and the A/C unit are operational. This luckily for the College has solved the problem of the odor diffusion although the intent was just to improve the cooling problems in that space.

A third source of potential leakage was found by inspection of the premises especially in the return plenum space where fire rated walls exist. The student observed several holes that compromised the separation of the different spaces such as corridors and classrooms on the second floor. It was also thought that these perforations will compromise the isolation of the kitchen areas from the other rooms on that floor such as classrooms and can contribute to the odor problem. Figures 3&4 depict these gaps in the structure.

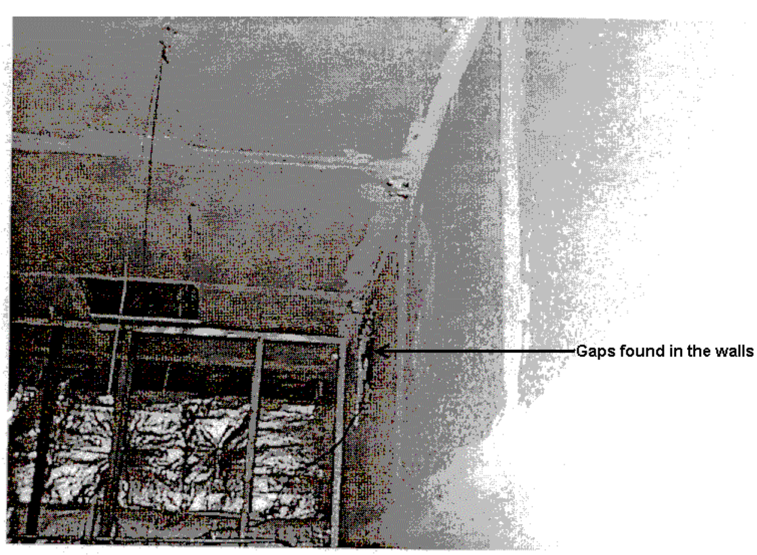

FIG - 3: GAPS FOUND IN THE WALLS

FIG - 4: GAPS FOUND IN THE WALLS

Finally it was noticed that the exhaust air leaves the building from a set of louvered registers that were placed right about the equipment room containing the air-handling units and the fresh air intake. Depending on wind conditions and ambient outdoor temperatures a condition can conceivably exist where the exhausted air can recirculate back into the fresh air registers and participate in compounding the odor problem from the kitchens. An attempt was made by the student to try to simulate the air flow phenomena by using a simplified 2-D CFD model to prove the point. His effort was met with partial success in pursuing this because of time constraints and also the need to use a more complete turbulent model to capture the physical phenomena of mixing for this problem scale. No results on this effort will be presented.

Some suggestions were made to the O&M to try to remedy the situation, although it had become an academic exercise at that point after the introduction of the new A/C unit over the production kitchen and banquet hall roof. Some of these were:

1-patch up gaps in the fire walls
2-rebalance air systems
3-isolate the cooking lab and production kitchens from the rest of the A/C system
4-some return registers in these spaces need to be blocked off completely
5-clean and better maintain exhaust fans to stay at their design flow capacities
6-improve the sequence control on all the air system units so that negative pressurization is assured for kitchens

CASE II

Definition:

Clark County School District, the local school district in the Las Vegas valley needed to have an assessment of which of two air handling systems would offer a better life cycle costs for a double-deck multi-zone unit versus a triple deck multi-zone unit coupled with either an air-cooled chiller or a water cooled chiller with an economizer. The driver for this study is the fact that the district has an active school retrofit program due to the fact that the energy expenditure of older buildings is about 30% more than newer one of the same size. The double and triple deck units are units that can provide heating and cooling simultaneously to different zones by mixing the cold/warm air streams together to obtain the desired supply air effect.

Discussion:

To try to answer this question one of my senior level students who has had some exposure to TRACE 700, a software code written by Trane Co. to analyze and calculate cooling/heating loads and perform economic analysis, put that code to work . The student had taken both HVAC courses that were offered by our department as mentioned above and was looking for an independent study course of three credits as allowed by our department for seniors or graduate students to be taken only once for credit.

The district gave us the layout drawings of one school to be retrofitted with the location and partition of all the relevant zones served by the different air-handling units. Also information was obtained on the different units and chillers from local suppliers. The total floor area of that particular school is 46,171 sq. ft. and the district's schools had barely any glass area on them except close to the main entrance of the building. The district wanted us to analyze four alternatives for this study as follows:

1-air-cooled chiller+triple deck+dry bulb economizer+gas fired furnace
2-air-cooled chiller+double deck+dry bulb economizer+gas fired furnace
3-water cooled chiller+triple deck+plate and frame water side economizer+gas fired furnace
4-water cooled chiller+double-deck+plate and frame water side economizer+gas fired furnace

The life cycle costs included the capital cost, fuel cost, maintenance and repairs over the expected life of the unit. Some of the information had to be obtained from past experience of maintenance personnel with the Clark County and from obtaining some guidance from the Means Guide.

The student obtained all the quantities needed to describe the envelope of the building and its different partitions and fed them into the appropriate input files required. Information on the number of students per classroom and number of computers per classroom along with the lighting were also obtained. Indoor temperatures and a general description of the set points for the economizers was also inputted. These economizers help cool the space in the off peak season where the ambient temperatures outside are not high but because of the cooling loads on the inner spaces required there may still be a need to run systems in the cooling mode. It is to be noted that the local electric energy pricing outlook in the Southern Nevada area has been witnessing a significant average increase for the last year and a half or so. The rates has skyrocketed to about 50% just in the last six months along and the outlook for at least residential customers was going to increase by another 25% or so come April 2002 to allow the local utility company to recover the cost of the purchased peak energy in the last year or so.

The details of the input files will not be discussed here for the sake of brevity. The code was run and the necessary analyses for the four cases were obtained. The student mad several contacts with the local technical community to try to fill the information gaps needed in completing the control sequence information. It must be said that a good student without any previous background in this code could at least get started on this code in a matter of a couple of weeks. The company also had a good technical support for answering any questions.

The final results that come out from the software analysis are different numerical values for the total cost of the utilities per year and over all the life span of the equipment estimated at 30 years as well as the yearly maintenance costs and their totals. Of course the capital cost is inputted initially to the code from previous information. For completeness, the study showed the following results as summarized by the following table:

Alterna-tive No.	Installed cost $	First Yr. Utili. Cost $	Final Yr. Utili. Cost $	First Yr. Maint. Cost $	Final Yr. Maint. Cost $	Life Cycle Cost $
1	829,470	109,244	340,695	16,322	50,903	3,071,365
2	808,800	109,119	340,304	16,022	49,967	3,031,472
3	875,270	83,367	269,348	19,274	60,109	2,876,920
4	854,600	88,300	275,379	18,974	59,174	2,864,937

It was found that alternative four was the best although number three was a close second. This showed to the student that at least in our geographical area the use of a water cooled chiller coupled with a water side economizer and a double deck multi-zone system usually will show the best performance. This conclusion was certainly not obvious to any of us at the start of the project.

CASE III

Definition:

The Energy Assessment Center (EAC) has been formed in the ME Dept. at UNLV to respond to the need from Nevada Power (NP) the local utility company in providing some technical assistance in analyzing the potential of a rebate that could be issued by NP to its large or medium size commercial customers if the technology they anticipated upon installing that would achieve a consistent reduction in the KW peak reduction defined between the hours of 1:00P.M. and 7:00P.M. and for the months of June to September.

Description

The purpose of the center is to help NP reduce the peak power demand which the company has to go out usually and purchase on the open market at very high prices. The EAC includes two undergraduate students, an assistant director and myself as the director of the center. List of names of potential customers are provided to us by NP with a note about the contact point for each entity and what they maybe contemplating on doing concerning energy conservation technologies. These technologies could range from applying highly reflective paints on the outer shell, changing to new HVAC equipment, applying occupancy room sensors to name a few. An initial visit is achieved between a representative of the customer and either myself or the assistant director which is then followed by an on site visit by all the members of the team to make a more detailed assessment. The students usually will obtain the necessary technical data under some supervision and technical tasks are assigned to the different group members after that. A weekly meeting is usually attended by all the team members to share in some of the results or participate in the discussion of how matters are developing.

One of the clients that we have visited recently is a hotel/casino in the Laughlin/Nevada area which is about 110 miles South of Las Vegas on the Colorado River. The need for that hotel was to assess the possibility of using room occupancy sensors in each of the guest rooms and also the need for the hotel to change their existing cooling towers to purchase three new ones whose technical information was provided to us. Briefly the room occupancy sensors are simply electronic sensors usually working with infrared rays to detect the existence of people in a certain room. The unit will usually then turn on the local air handling unit i.e. a fan coil unit , and cooling will proceed until the desired thermostat set point. If the room is not occupied then sensor will set-back the room temperature to some higher temperature that can be changed on that thermostat. Many types of sensors are available on the market though when you look at what most of them do there are several similarities of operation. To try to estimate the potential savings for this technology in hotel rooms especially with the particular guests that come to a casino NP had performed an experimental study earlier on this matter. The study looked at three types of these sensors used in four Las Vegas gaming properties and determined that a certain average percentage of electric power savings could be applied to the total cooling load which would otherwise be reached had the property not used this technology. Of course due to the nature of the randomness of the living habits for typical guests that normally frequent hotel/casinos this study would not have been realistically possible by performing simulations without some specific statistical patterns of lifestyle been assumed.

To try to make use of the results of the NP study the students had to perform a cooling load calculation using TRCAE 700 and to determine the maximum KW demand used for that particular property during the summer season. The reason for doing that as opposed to simply depending on the actual electric power demand provided to us from NP meter logs is that the cooling units which provided cooling for the guest towers also provided cooling to other parts of the casino space. This made it impossible to separate out the effect of the non hotel room space energy consumption from the total metered electric consumption. Again this particular student who ran TRCAE was helped a little bit in setting up the problem by the student who performed the study in case II. TRACE of course has in it a complete year's weather information for the Las Vegas area to help in obtaining the load analysis on an hourly basis. The study was performed over the entire year but with electric power demand reduction observed for the summer months. Having established the peak of power demand for the summer months this percentage ratio of savings as provided by the NP report was then applied. The student then calculates the total rebate as governed by the formula set by NP which is the total KW demand saved will then be multiplied by $100 and hence an estimate of the total rebate will be obtained. NP power has a maximum cap on any entity's rebate of $25,000. The report that the student usually prepares with some guidance also will include an estimate of the payback period for using this technology. A simple payback period is applied, as the estimate of how electricity prices in our area maybe moving is anybody's guess. Of the study will try to use an averaged installed price of the technology as the customer usually has not decided which technology exactly to use. It is to be noted that in all our reporting we advise the customer (whose getting this service for free from NP) that they need to contact an engineering firm eventually to make sure what is exactly promised as far as savings and initial costs. For that particular hotel it was estimated that the total design cooling load for the hotel guest tower was approximately 1000 tons refrigeration. This meant that an estimated 250 ton of refrigeration can be expected according to NP's student on room occupancy sensors. It also would mean a potentially $25,000 in rebate would come the hotel's way if the management decided on implementing these changes.

The study for the assessment of the replacement of the existing cooling towers with the new ones is not complete. Although theoretically it follows similar footsteps just as the first one for case III. The difference for the operation of the cooling towers lies in the fact that the fan power requirements are different (more efficient air flow in newer unit) and the temperature approach values for each set of towers is different which will affect the thermal performance of the cooling towers (better heat/mass transfer in newer unit). This physical situation can also be simulated again by the use of TRACE 700.

SUMMARY AND COMMENTS

The three cases above were discussed rather briefly to shed some light on their technical content. Some points about the studies can be summarized as follows:

1- students dealt with real world HVAC problems and not textbook ones.
2- Students also learn that what is designed on paper unfortunately is not always what is installed especially with an evolving structure for a university application
3- Students learned by field inspections and doing some experimental measurements in one case how HVAC systems can behave.
4- Students learned some valuable facts by just interacting with local people in the industry about various performance of HVAC units.
5- Students learned how to use a state-of-the-art simulation software such as TRACE 700.
6- Students learned how they need to communicate with a variety of clients from O&M people in a university atmosphere to various management levels in industry.
7- Students of course learned the value of trying to stick to schedule and deliver reports on time.

8- In the case where students used the code I would have to say that the students were increasingly enthused about using it and in some cases took it upon themselves to test other cases besides what they were asked to do.
9- I think the experience from an instructor and a student's point of view was gratifying and challenging at the same time.
10- This approach is considered as a "non formal' and "non traditional" approach to teaching or more appropriately learning about different facets of HVAC and energy conservation in general. Hence a word of caution should be in place and that is this should not be probably attempted on a novice or a new comer to the field. Some course preparation or prior experience even on a practical level should be had by the student before venturing into this approach.
11- A reasonable knowledge of PC operations and use of general window based codes would probably be a great help to the student.
12- The author of this paper is planning to expand the use of this approach to the study of HVAC in general to increase the interest of the students in this field as this is one of the ways that a student can "get his/her feet wet" in this area of technology.
13- It was an "eye opener" again for the author who has had practical experience in the field for several years to be reminded that what reality and execution of engineering jobs in the field is much different than what one normally encounters in a research area, especially when this entrenchment has been for several years.
14- As this is a relatively new effort in my approach to teaching and engaging student in HVAC related subjects. As a starter, the author envisions dedicating probably the last two meeting times in each of the two courses taught to discuss and present in a relatively brief way some of the completed studies that may have been accomplished recently. The topics discussed will probably change from year to year to accommodate the new knowledge or case studies that have been completed most recently. Obviously a very detailed discussion in such a short time (i.e. two contact hours) would not be feasible. It is hoped though that through this short introduction and potential for learning HVAC that the encounter would spark the students interest who may come later wanting to do an independent study in this area.

REFERENCES

Forsberg C.; " Use of Computers in Undergraduate HVAC Design", ASEE 2001 Annual Meeting Proceedings, session 2793.

Alexander, R.C.; "Development of a System-Design-Oriented HVAC/energy Curriculum", ASHRAE Transactions pt. 2, 1990, pp.637-642

Meredith, D.B.; "Computer-aided Design (CAD) Package for Teaching HVAC design", ASHRAE Transactions, pt. 2, 1990, pp. 643-647

Fung, A.S.; "Design and Construction of a Computer-Controlled Laboratory Air Conditioning Unit", Int'l J. of Mech. Eng'g Education, vol. 19, n 1, 1991, pp. 69-76

Santos, J.J.; “Controls Education: More Critical Than Ever”, HPAC Heating, Piping, AirConditioning Engineering, 2001, pp. 10-15

Stevens, J.W.; Hodge, B.K.; Jalalzadeh-Azar, A. ; “Desicant Instruction Module for HVAC Courses”, ASEE Proceedings, June 1997, pp. 1-9

Oppenheim, P.; “Meeting the HVAC needs of the Building Construction Professional”, ASHRAE Transactions, vol. 100, 1, 1994, pp. 1614-1618

Chen, C.C.; “Energy Audit Project and HVAC Education”, Proccedings of the ASME Winter Conference, Nov. 1993, pp.1-3

Nasr, Karim J.; “Developing Real-World, Hands-on, Low Cost, Multi-disciplinary Experiences for Undergraduate Students”, ASME-HTD, v 361-3, 1988, Anaheim, CA, pp. 43-47