ESL-TR-93/10-03

LoanSTAR Monitoring and Analysis Program

Summary of UTMB O&M Project:

ENERGY CONSERVATION POTENTIAL IN FIVE BUILDINGS

Submitted to the
Texas State Energy Conservation Office
By the
Monitoring and Analysis Task E (O&M)

Dr. Mingsheng Liu
Mr. Aamer Athar
Dr. T. Agami Reddy
Dr. David Claridge, Principal Investigator
Dr. Jeff Haberl

October, 1993

DISCLAIMER

Table of Contents

Summary of UTMB O&M Project:

ENERGY CONSERVATION POTENTIALS IN FIVE BUILDINGS

1. INTRODUCTION

The quality of operation and maintenance is a key factor influencing building energy costs. Traditional O&M energy conservation practice and research have focused on 1) fixing damaged parts; 2) reducing excessive operation hours; and 3) utilizing appropriate nighttime setbacks. These traditional O&M measures can reduce energy consumption substantially in many buildings. However, substantial additional reduction of energy consumption can sometimes be realized after these traditional O&M measures are implemented by optimizing weather dependent cold deck and hot deck reset schedules and optimizing cold deck set points when the outdoor air is pre-treated prior to mixing with return air. The optimized cold deck set point coordinates the cold deck setting with hot deck setting to minimize the whole system energy consumption. These two measures often reduce energy consumption substantially and can be implemented by just tuning the Energy Management and Control System (EMCS) program. Therefore, we call these measures or concepts the "soft tune up" measures.

This report is a summary of five reports (references 1 to 5) which provided detailed descriptions of an O&M investigation of the following five buildings on the UTMB campus: 1) John Sealy North Building(JSN); 2) Clinical Science Building(CSB); 3) Basic Science Building(BSB); 4)Moody Library Building(MLB); and 5) John Sealy South Building(JSS).

In these five buildings, the soft tune up is the major O&M measure identified. This report briefly describes the buildings, summarizes the methodology used and the O&M

measures identified for each building, presents simulated energy savings, measured savings and conclusions.

2. BUILDING & HVAC SYSTEM INFORMATION

The JSN building is a two-story structure. It houses the medical operating rooms on the second floor and associated facilities on the first floor. The CSB building is a six-story classroom building with a few laboratories. The BSB is a seven-story building which includes offices, classrooms, labs and storage spaces. The MLB building is a six-story library with a core 1st floor, 5th and 6th floors. It includes stack area, offices, conference rooms and necessary service facilities. The JSS building is a 12-story in-patient care facility. These buildings range in size from 67,000 ft^2 to 373,000 ft^2 and have a total floor area of 779,000 ft^2 (see Table 1). The building's annual energy costs vary from $194,900 to $991,000, totalling $2.7 million dollars of which about 78% is thermal energy cost. The normalized energy cost varies from $2.65/$ft^2$yr to $6.64/$ft^2$yr with an average of $3.48/$ft^2$yr. More detailed information is supplied in references 1-5.

Table 1: Summary of Building Information

Building	JSN	CSB	BSB	MLB	JSS	Total
Type	Hospital In-patient	Lab. & Class	Lab. & Class	Library	Hospital Operation	
Floor area (ft^2)	75,700*	124,900	137,900	67,400	373,000	778,800
Thermal Energy ($/yr)	$405,300	$235,300	$573,900	$153,200	$759,000	$2,126,600
Electricity ($/yr)	$96,800	$115,200	$97,000	$41,800	$231,600	$582,400
Total Energy ($/yr)	$502,100	$350,500	$670,900	$194,900	$990,600	$2,709,000
Total Energy $/$ft^2$yr	$6.64	$2.81	$4.87	$2.89	$2.65	$3.48

* Including a kitchen area (18,000 ft^2) within John Sealy Hospital

There are three basic types of air conditioning systems in these five buildings. One is the dual duct constant volume system with pre-treated outdoor air intake. This system is used in the CSB, JSS, and JSN buildings. A schematic diagram of this system is shown in Figure 1.

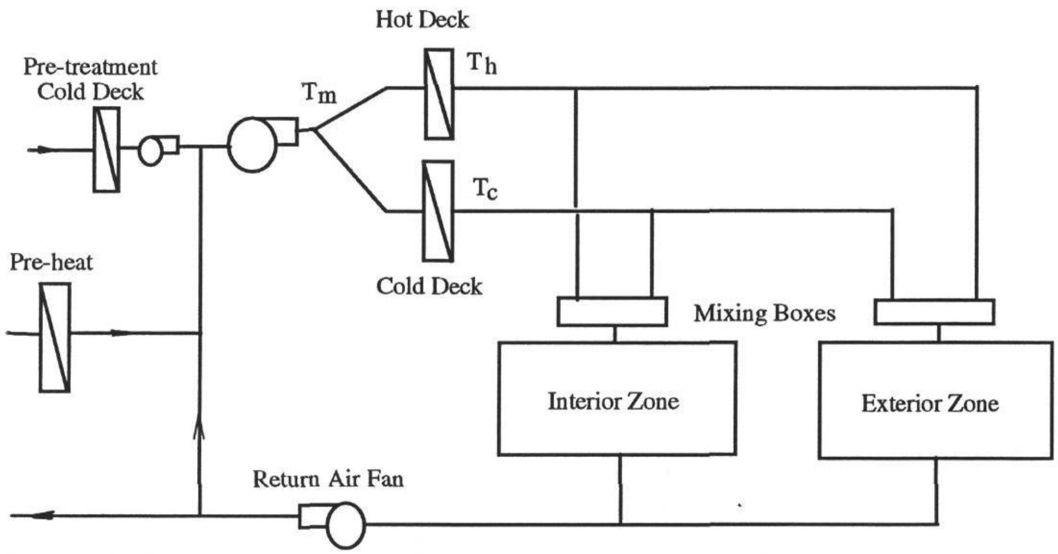


Figure 1: Schematic Diagram of the Dual Duct Constant Air Volume System with Pretreated Outdoor Air Intake as used in the CSB, JSS and JSN Buildings

The second type of system is the single duct constant air volume system which is used in a portion of the JSN building. The diagram of this system is shown in Figure 2. Note that the system uses 100% outdoor air.

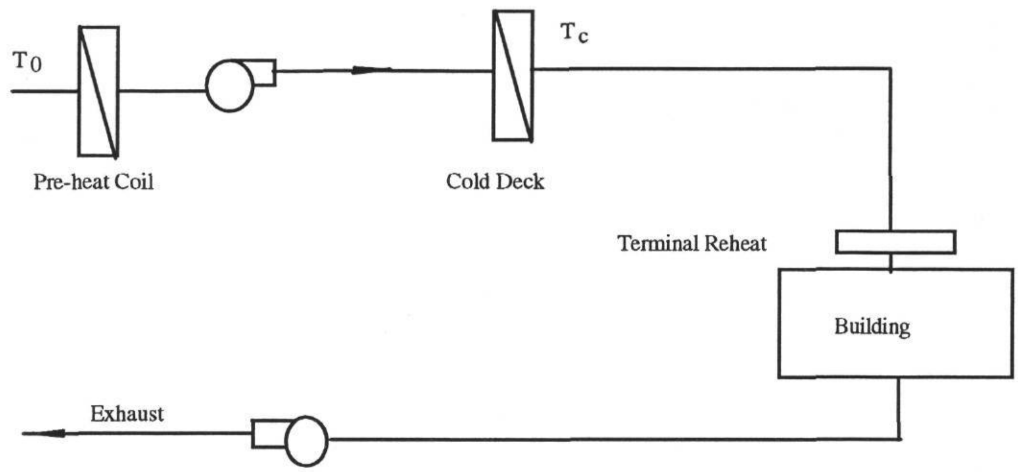


Figure 2: The Schematic Diagram of the Single Duct Constant Air Volume System

The third type of system is a modified dual duct constant air volume system with part of the air reheated as shown in Figure 3. This system is used in the MLB and BSB buildings. Note that the cooling coil cools all of the mixed air.

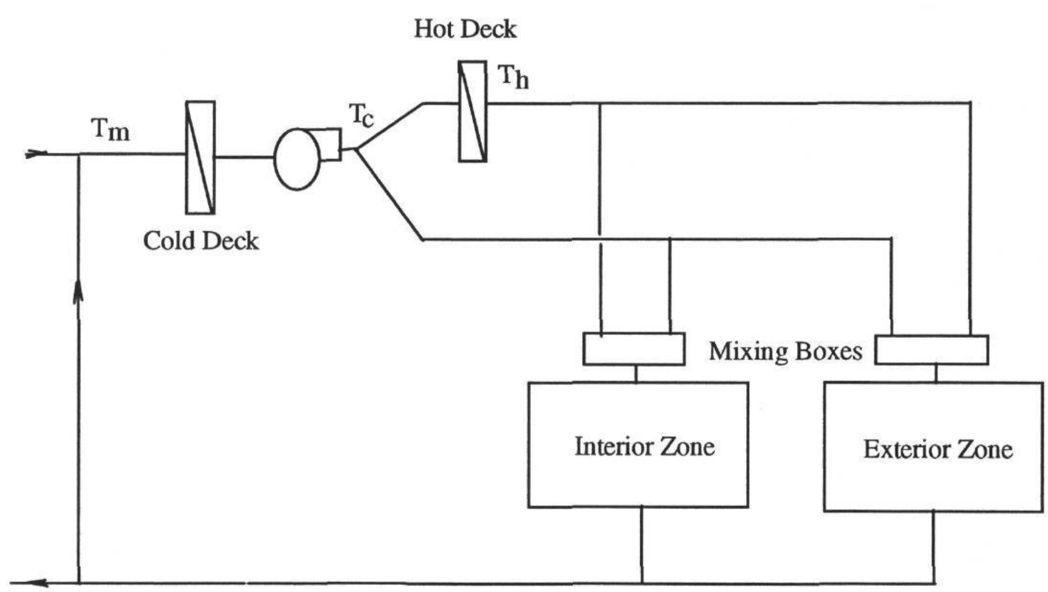


Figure 3: Schematic Diagram of Modified Dual Duct Constant Air Volume System as Used in MLB and BSB Buildings

3. METHODOLOGY

The methodology used to explore energy conservation opportunities is outlined below:

1. *LoanSTAR information base browsing*. The LoanSTAR information base includes
   - (i) LoanSTAR Database (LSDB), which contains continuously measured hourly energy and weather data;
   - (ii) the site description note book (SDN), which contains up-to-date HVAC system, lighting, building envelope, occupancy and audit report information;
   - (iii) the Inspection Plot Notebook (IPN), which contains plots of all monitored data channels for each week;
   - (iv) the Monthly Energy Consumption Report (MECR), which details each month's energy performance and summarizes energy performance history; and
   - (v) the Annual Energy Consumption Report (AECR), which summarizes last year's energy performance.
2. *Site visit/system examination*. The purpose of the site visit includes:
   - (i) contacting personnel at the site agency and exchanging opinions on energy conservation potentials;
   - (ii) verifying information from the LoanSTAR information base by walking through the building and mechanical rooms, and talking with operators and office personnel;
   - (iii) examining the feasibility of potential energy conservation measures by visually checking and discussing cost limitations, equipment limitations and institutional limitations;
   - (iv) exploring potential new energy conservation measures; and

(v) collecting system operating information, such as cold deck and hot deck temperatures, air flow rates, and relevant EMCS information.

3. *Data quality check.* The LoanSTAR data are compared with EMCS measured data. If the two sets of data are fairly close, the LoanSTAR data will be used to calibrate the simplified model without correction. If the LoanSTAR measured data and EMCS measured data exhibit significant differences, additional checks are used to identify reliable data for the simplified model calibration described below.

4. *System modeling and calibration.* The HVAC systems and the building are modeled with a customized model which incorporates key physical and system characteristics, representing the building and its systems by a set of equations which are programmed into a computer. The simplified computer model uses measured daily average ambient temperature and dew point to predict daily average chilled water and hot water energy consumption. Finally, the predicted energy consumption is compared with the measured consumption. If the predicted consumption matches measured energy consumption, then the simplified computer model and its associated parameters, such as air flow rate, cold deck and hot deck settings, and internal gains, are considered calibrated and hence appropriate parameters for the building. Otherwise, additional effort is needed to match the measured and predicted consumption by adjusting some parameter values until agreement with the consumption data is obtained. These adjustments of the basic parameters are verified with a site measurement or other methods.

5. *Energy conservation simulation & savings calculations.* The building energy consumption is minimized using energy conservation measures while the following conditions are satisfied:

(i) room temperature should not be changed;

(ii) room relative humidity should be at the same level after energy conservation measures are included in the model;

3) the air flow rate to each room should not be changed; and

4) the maximum air flow rate through cold and hot decks and ducts should not exceed their capacities or design values.

Energy savings are calculated as the difference between the base model's (calibrated model) annual energy consumption and the optimized model's (with energy conservation measures) annual energy consumption.

6. *Feedback from UTMB physical plant personnel.* UTMB personnel comment on the energy conservation measures and provide information necessary to modify these measures if any. The simplified model simulation might indicate that some of the EMCS measured values did not represent true values. These parameters are discussed during the feedback meeting and are measured jointly by both LoanSTAR and UTMB personnel.

7. *Refinement of simulation & savings calculations.* All the suggestions and findings are incorporated into the simplified model and the potential savings recalculated.

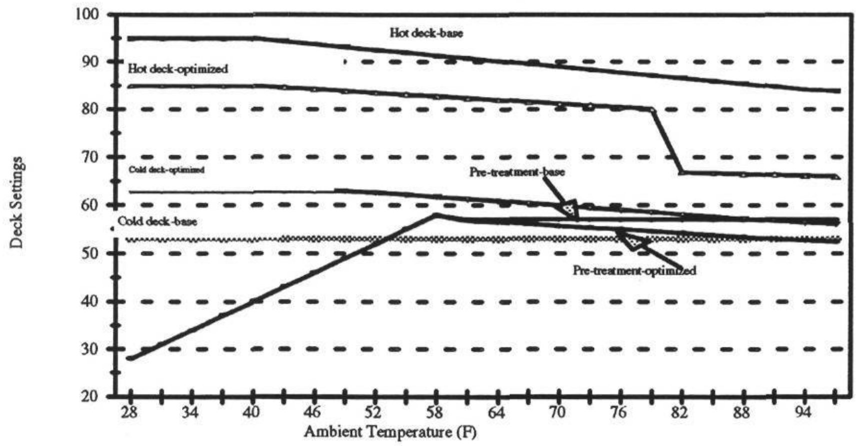
4. SOFT TUNE UP

The cold deck and hot deck reset schedules and the set points have been optimized using the above methodology. This section summarizes the soft tune up results for each building.

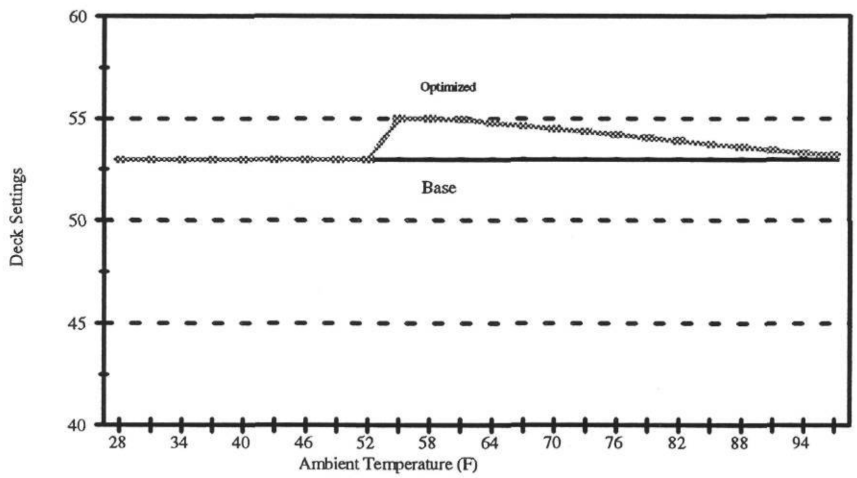
4.1 John Sealy North Building:

The soft tune up is the only O&M measure in this building. The optimized schedules decrease the pre-treatment cold deck temperature and increase the main cold deck temperature for the DDCV system, and increase cold deck temperature when ambient temperature is lower than design temperature for the SDCV system. The optimized schedule changes deck settings according to the ambient temperature and can be implemented by reprogramming the EMCS.

The operation schedules are compared in Figure 4. The base or current schedule has the pre-treatment cold deck temperature (57 °F) higher than the main cold deck temperature (53 °F). The optimized schedule has the pre-treatment cold deck temperature lower than the main cold deck temperature. This change is called cold deck setting optimization.



(4a: DDCV System)



(4b: SDCV Systems)

Figure 4: Comparison of the Base and the Optimized Cold & Hot Deck Schedules at the John Sealy North Building

Table 2: Comparison of Operation Schedules at the JSN Building

Item	Base	Optimized
	DDCV	

O. A. treatment coil	If T0>60 °F then
	57 °F,
	else
	Off
		If T0>60 °F then
		Min(57, 57-0.125*(T0-60))
		else
		off

Main cold deck	53 °F	Min(63, 63-0.15*(T0-50))

Hot deck	Min(95, 85+0.2*(90-T0))	If T0<80 then
		Min(85, 85-0.125*(T0-40))
		Else
		off

	SDCV	
Cold deck	53	Min(55, 55-0.05*(T0-60))

4.2 Clinical Science Building:

The soft tune up is the only O&M measure in this building. The optimized schedules decrease the pre-treatment deck temperature and increase the main cold deck temperature. The optimized schedule changes deck settings according to the ambient temperature and can be implemented by the EMCS without hardware changes. The optimized and the base schedules are compared in Table 3 and Figure 5.

Table 3: Comparison of Operation Schedules at the Clinical Science Building

Item	**Base**	**Optimized**
Main cold deck	54.5 °F	Min(62, 62-0.125*(T0-60))

Pretreatment cold deck	57 °F	If T0>60 then
		Min(57, 56-0.05*(T0-60))
		Else
		57

Main hot deck	If T0<80 °F then
	Min(100, 80+0.5*(80-T0))
	Else
	85
		If T0<80 then
		Min(85, 85-0.25*(T0-60))
		Else
		off

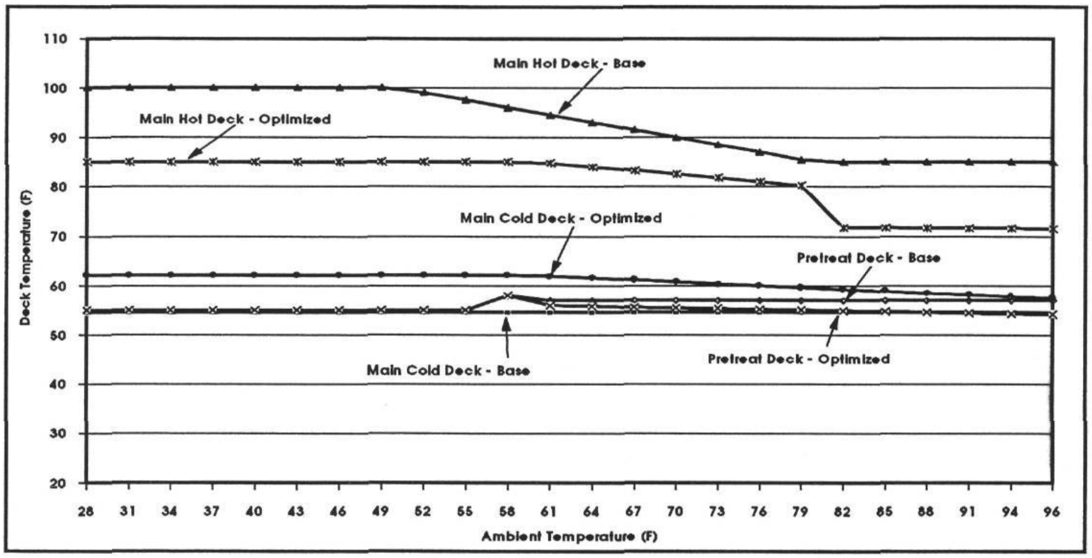


Figure 5: Comparison of the Base and the Optimized Deck Schedule at the Clinical Science Building

4.3 Basic Science Building:

The soft tune up is the only O&M measure in this building. The optimized schedule simply increases the cold deck temperature. The optimized schedule changes the cold deck setting according to the ambient temperature and can be implemented by reprogramming the EMCS without hardware changes. The optimized and the base schedules are compared in Table 4 and Figure 6.

Table 4: Comparison of Operation Schedules at the Basic Science Building

Item	Base	Optimized
Cold deck	54 °F	Min(61, 61-0.09*(T0-58))

Hot deck	If T0<80 then
	Min(90, 80-0.25*(T0-75))
	Else
	80
		If T0<80 then
		Min(90, 80-0.25*(T0-75))
		Else
		80

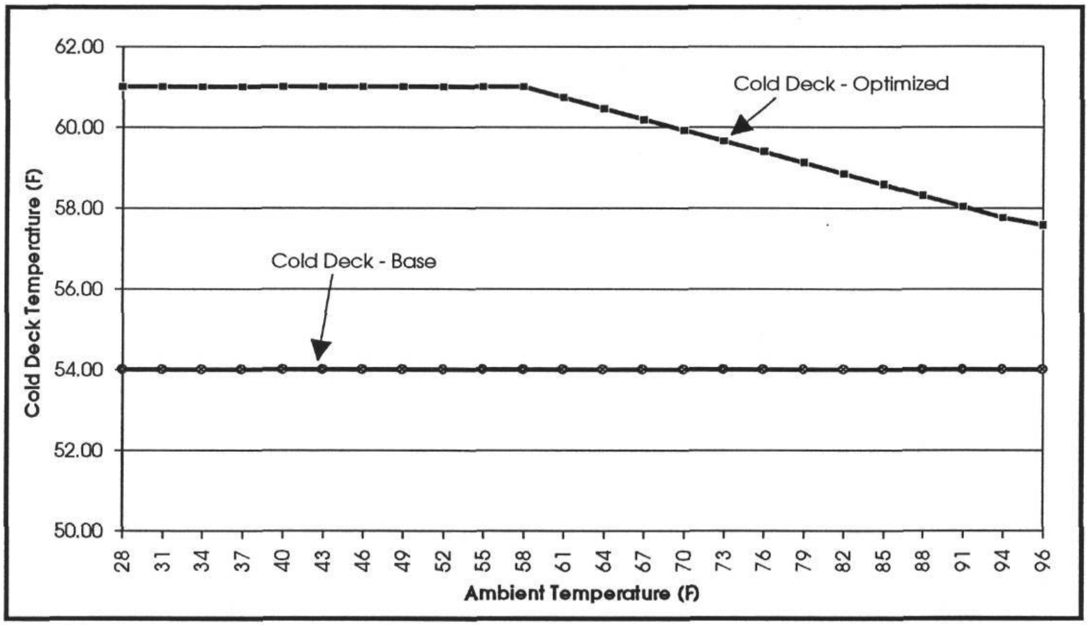


Figure 6: Comparison of the Base and the Optimized Cold & Hot Deck Schedule at Basic Science Building

4.4 Moody Library Building:

The soft tune up is the only O&M measure. However, the potential savings due to economizer cycles are also investigated. The optimized schedule increased cold deck temperature, and decreased hot deck temperature when the ambient temperature is higher than 80 °F. However, it should be noted that this cold deck increase should be implemented using a partially closed cold deck. The optimized and the base schedules are compared in Table 5 and Figure 7.

Table 5: Comparison of Operation Schedules at the Moody Library Building

Item	Base	Optimized
Cold deck	56 °F	Min(62, 60-0.2*(T0-85))

Hot deck	If T0<80 then
	Min(90, 80-0.25*(T0-75))
	Else
	80
		If T0<80 then
		Min(90, 80-0.25*(T0-80))
		Else
		70

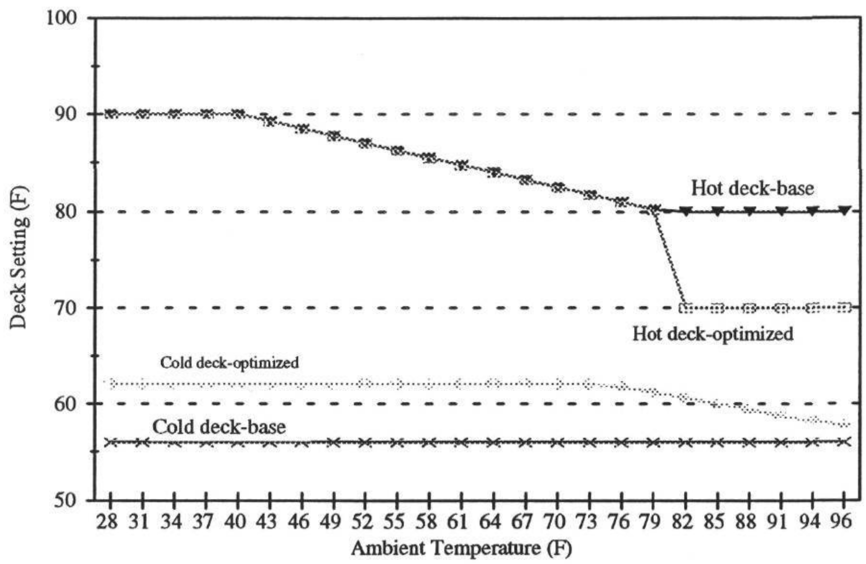


Figure 7: Base and Optimized Cold & Hot Deck Schedules at the Moody Library Building

4.5 John Sealy South Building:

The O&M measures include the soft tune up and delamping in this building. The optimized schedule increased both the pre-treatment and main cold deck temperatures in this building due to mal-functioning. The optimized and the base schedules are compared in Table 6 and Figure 8.

Table 6: Comparison of Operation Schedules at the John Sealy South Building

Item	Base	Optimized

O. A. treatment coil	If T0>60 °F then
	52.8 °F,
	else
	Off
		if T0>60 °F then
		Min(54, 54-0.05*(T0-60))
		else
		off

Main cold deck	51.5 °F	Min(59, 59-0.05*(T0-50))

Hot deck	If T0<80 then
	Min(95, 90-0.25*(T0-75))
	Else
	85
		If T0<80 then
		Min(85, 85-0.25*(T0-60))
		Else
		75

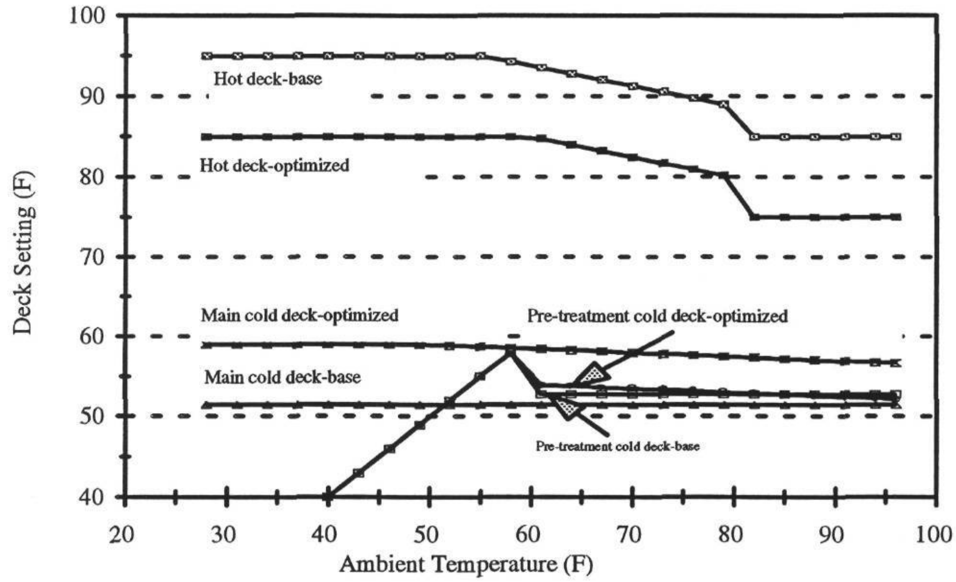


Figure 8: Base and Optimized Cold & Hot Deck Schedule at the John Sealy South Building

5. OTHER O&M MEASURES

5.1 Delamping at the John Sealy South Building

The O&M staff observed that lighting levels in elevator lobbies and corridors appeared to be excessive in the John Sealy South Building. Table 7 shows that the current levels are substantially higher than the Illuminating Engineers Society (IES) standard. Since the fixtures in these areas are 2ft. × 4ft., 4 lamp, lay-in troffers, they would easily lend themselves to delamping which would decrease the electrical load by 88 Watts per fixture if two lamps and a ballast are disconnected. In addition, a formal program of turning-off lights in corridors and elevator lobbies after hours would contribute to less energy consumption.

Table 7: Summary of Lighting Survey in John Sealy South Building

Floor	Area	Measured Footcandles	Recommended IES Footcandles Day	Night
3	Elevator Lobby	132	50	20
3	Day Surgery Corridor	85	30	30
5	Elevator Lobby	149	50	20
5	Main Corridor	133	20	3
5	Patient Rooms Corridor	39	20	3
5	Nurses' Station	156	70	30
7	Elevator Lobby	150	50	20
7	Main Corridor	127	20	3
7	Nurses' Station #1	150	70	30
7	Nurses' Station #2	175	70	30
7	Patient's Room Corridor	80	20	3

5.2 Using Economizer Cycle at the Moody Library Building

The potential savings of economizer cycles are also investigated since they may be implemented at low cost. The economizer uses the following control strategy: if the ambient temperature is lower than cold deck supply air temperature, then the return air fraction is calculated by the formula:

$$\beta = \frac{T_c - T_o - \delta T}{T_r - T_o}$$

where β is the return air fraction, T_c is the cold deck supply air temperature, T_o is the ambient temperature, T_r is the return air temperature, and δT is the temperature rise due to the supply air fan.

If the ambient temperature is higher than the cold air supply temperature but lower than a critical temperature (T_r -10 °F), then the return air should be eliminated. If the ambient temperature is higher than the critical temperature, then the return air fraction was assumed to be 0.96, which is the current operation return air fraction. Note that the critical temperature is chosen according to the relationship between ambient dry bulb and typical dew point temperature in Galveston. This critical temperature allows the temperature economizer to perform similar to an enthalpy economizer.

6. POTENTIAL ENERGY SAVINGS

The potential energy savings due to soft tuning up and other O&M measures were investigated using the simplified model analysis. The potential cost savings were calculated using the following unit energy prices, \$7.30/MMBtu for chilled water and \$5.055/MMBtu for condensate. The potential annual savings are summarized in Table 8. The bottom row shows savings as percentages of the total annual costs.

Table 8: Summary of Potential Costs Savings Due to Optimized Operation Schedules

Savings	JSN	CSB	BSB	MLB	JSS	Total
Chilled water \$/yr	54,300	55,700	108,700	27,700	124,500	370,900
Condensate \$/yr	12,700	18,000	47,300	18,800	50,100	146,900
Total \$/yr	67,000	73,700	156,000	46,500	174,600	517,800
\$/ft^{2}yr	0.84	0.59	1.13	0.69	0.47	0.66
%	13%	21%	23%	24%	18%	19%

The soft tune up can reduce annual energy cost by amounts from \$46,500 in the Moody Library Building to \$174,600 in the John Sealy South Building as shown. The potential savings range from 13% to 24% of the building consumption with an average of 19%.

The potential savings due to economizer cycles is about \$28,100/yr in the Moody Library. The potential savings due to delamping in the John Sealy South Building is about \$45,900. The total potential savings are about \$591,800/yr or 23% of total annual cost (\$2.7 Million dollars).

The potential annual savings from soft tune-up range from \$0.47/ft^2 to \$1.13/ft^2 with an average of \$0.66/ft^2 yr. It should be emphasized that these savings are purely due opimizing cold deck and hot deck reset schedules.

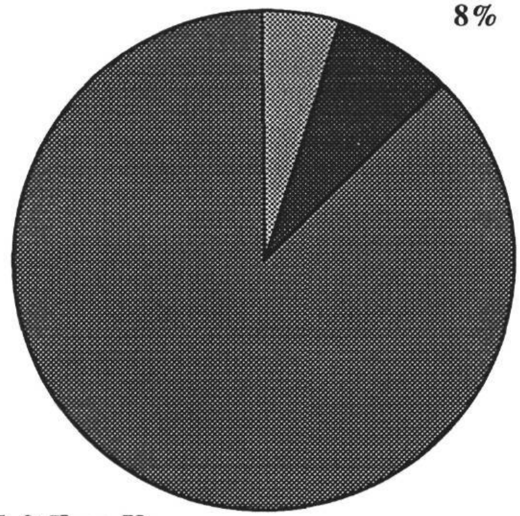


Figure 9: Comparison of Potential Savings Due to Different Measures
(The Total Potential Savings is $591,800/yr, or 22% of Annual Energy Costs)

7. MEASURED SAVINGS

In the Basic Science Building, the cold deck temperature for both the air handling units was raised from 54 ^{O}F to 59 ^{O}F on July 2, 1993. Reduction in chilled water and condensate consumption was immediately noticed. Data from July 2, 1993 to October 25, 1993 were used to calculate the savings for 117 days by using a single linear regression model. Figure 10 shows the chilled water consumption from January to July 2 as squares and after July 2nd as "+". Figure 11 shows the pre-and post-condensate consumption using the same symbols. The drop in energy consumption is very noticeable. As of October 25, 1993 the Basic Science Building has saved 5,840 MMBtu in chilled water energy and 3,100 MMBtu in condensate energy, which amounts to $42,600 and $15,600, respectively. The total measured savings for 117 days is $58,200 which is consistent with the simplified model savings prediction of $156,000 per year.

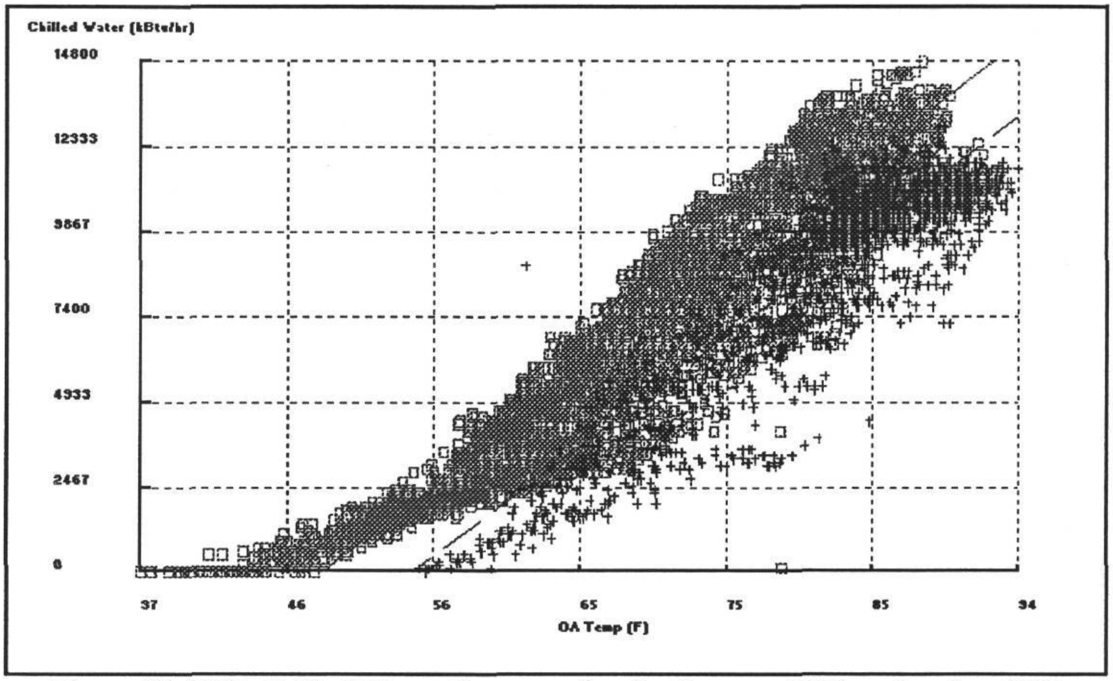


Figure 10: BSB Chilled Water Consumption for January 1993 to October 1993
□ Represents Data Before Raising Cold Deck Temperature to 59 °F
+ Represent Data After Raising Cold Deck Temperature to 59 °F

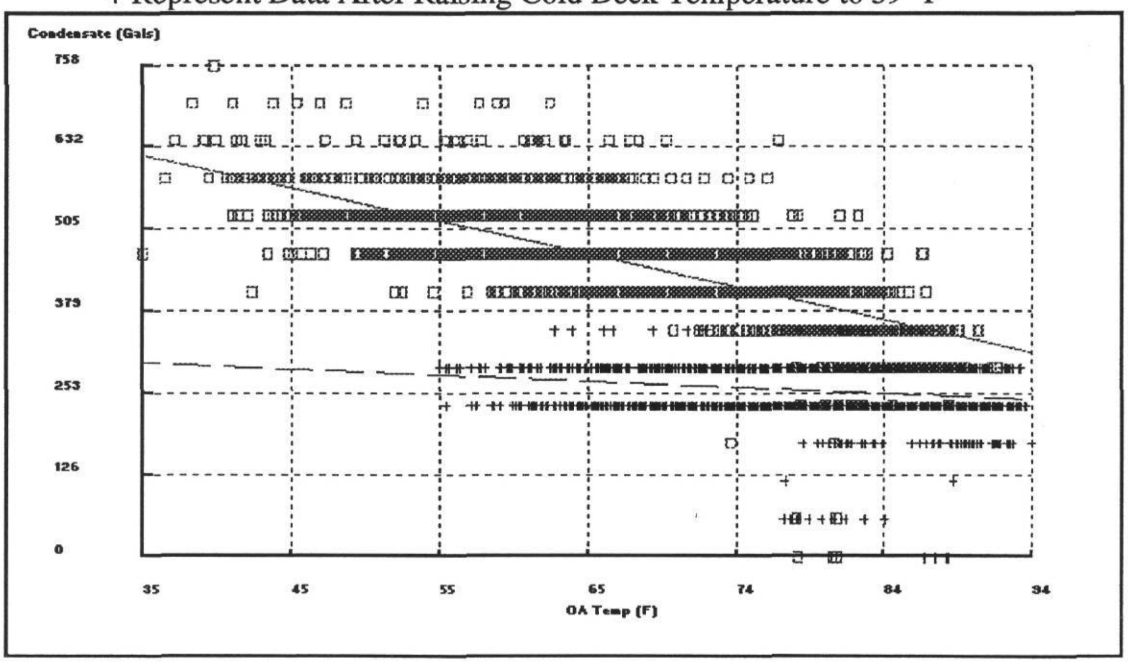


Figure 11: BSB Condensate Consumption for January 1993 to October 1993
□ Represents Data Before Raising Cold Deck Temperature to 59 °F
+ Represent Data After Raising Cold Deck Temperature to 59 °F

8. CONCLUSIONS

The quality of operation and maintenance is a key factor that influences building energy costs. Although the traditional O&M measures (fixing damaged or malfunctioning parts, reducing excessive operating hours, and making appropriate nighttime setbacks) can reduce the building energy consumption substantially, the building energy consumption can be further reduced by using optimized weather dependent cold deck and hot deck settings and optimized system operating settings when the outdoor air is treated by a separate unit. The optimized operating settings coordinates the cold deck and hot deck settings to minimize the system energy consumption. These two measures are called soft tune-ups to distinguish them from traditional O&M measures. These measures require a thorough overall system optimization, but require no investment.

The potential energy savings due to soft tune up O&M measures has been investigated at five UTMB buildings, which are properly operated according to the traditional standard. It has been found that these soft tune-ups can reduce the total annual energy cost by \$517,800, or 19%. The annual per square foot saving ranges from \$0.47/ft^2 yr to \$1.13/ft^2 yr with an average of \$0.66/ft^2 yr.

Delamping at John Sealy South Building can reduce annual electricity costs by an additional \$46,000. The economizer cycles may reduce annual energy costs by \$28,000 at Moody Library building. The total potential energy cost reduction is about \$591,000/yr or 23% of the annual total energy cost.

About \$58,200 savings have been measured in four months at the Basic Science Building due to these measures. The measured savings are consistent with the simplified model prediction for this building.

REFERENCES

1. M. Liu, A. Athar, T. A. Reddy, J. Houcek, D. E. Claridge, and J. Haberl, 1994, "Potential Operation and Maintenance (O&M) Savings in the John Sealy South Building", ESL-TR-93/10-06, Internal Report of the Energy Systems Laboratory, Texas A&M University, College Station, Texas.

2. M. Liu, A. Athar, T. A. Reddy, D. E. Claridge, and J. Haberl, 1994, "Potential Operation and Maintenance (O&M) Savings in the John Sealy North Building", ESL-TR-93/10-07, Internal Report of the Energy Systems Laboratory, Texas A&M University, College Station, Texas.

3. M. Liu, A. Athar, T. A. Reddy, D. E. Claridge, and J. Haberl, 1994, "Potential Operation and Maintenance (O&M) Savings in the Basic Science Building", ESL-TR-93/10-04, Internal Report of the Energy Systems Laboratory, Texas A&M University, College Station, Texas.

4. M. Liu, A. Athar, T. A. Reddy, D. E. Claridge, and J. Haberl, 1994, "Potential Operation and Maintenance (O&M) Savings in the Clinical Science Building", ESL-TR-93/10-05, Internal Report of the Energy Systems Laboratory, Texas A&M University, College Station, Texas.

5. M. Liu, A. Athar, T. A. Reddy, D. E. Claridge, and J. Haberl, 1994, "Potential Operation and Maintenance (O&M) Savings in the Moody Library Building", ESL-TR-93/10-08 Internal Report of the Energy Systems Laboratory, Texas A&M University, College Station, Texas.

ACKNOWLEDGMENTS

The contributions from the Physical Plant Department at UTMB are much appreciated; the EMCS measured energy data provided and discussions of the optimized operation schedules were invaluable. In particular, we would like to thank Mr. White, the executive director of the Physical Plant Department (now the Director of Energy Conservation and Management Department), Mr. John Windham, the HVAC foreman, and Mr. Steven Hodgson. We would also like to thank Susan Swanson for her editing assistance.