UNIVERSITY OF CALIFORNIA, RIVERSIDE

STATISTICS-COMPUTER BUILDING HVAC STUDY

FINAL REPORT

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CHAPTER 1
EXECUTIVE SUMMARY

The University of California, Riverside (UCR) commissioned Goss Engineering, Inc. (GEI) to analyze the Statistics-Computer Building existing HVAC system issues and to develop recommendations to alleviate the existing HVAC systems issues.

BACKGROUND

Statistics-Computer Building was originally constructed in the 1970s. Since then, many modifications have been made to the building, including room additions, and room conversions to a different usage. The building is currently experiencing thermal discomfort in some of the rooms.

RECOMMENDATIONS

GEI evaluated and analyzed the existing HVAC systems and recommends the following options to resolve the current thermal challenges:

- Replace the existing air-handling units with new cooling only units and terminal reheat coils
- Rebalance existing system
- Clean duct system
- Install fire-rated ceiling in corridors on the first and second floor
- Install direct digital controls (DDC)
- Install chilled water fan coil units for computer rooms on the second floor

The estimated budget construction cost for the recommended option is approximately **$1,100,000.**

CHAPTER OUTLINE

Chapter 2 provides a background on the Statistics-Computer building and the existing HVAC system.

Chapter 3 provides brief a description of the existing HVAC system.

Chapter 4 presents the existing HVAC system analysis.

Chapter 5 provides the recommended HVAC system modifications.

Chapter 6 provides other findings and recommended modifications.

Chapter 7 provides estimated budget construction cost for the recommended modification options.

Cooling load calculations are provided in the appendix.

CHAPTER 2

BACKGROUND

This chapter provides a background information on the Statistics-Computer Building and its occupancy as well as some of the current thermal discomfort complaints, which lead to this HVAC study. **Chapter 3** provides detailed information and reviews the existing building HVAC system.

EXISTING BUILDING

The Statistics-Computer Building is a Type1 construction, "B" Occupancy building and was originally constructed in the 1970s to house the Computer Science Department.

The building has two floors plus a basement. The first floor is mainly occupied by the computer server room, Division of Biomedical Science offices and International Educational Center. The second floor houses the Statistics Department. The basement houses laboratories, exam rooms and classrooms in the Biomedical Science Division.

Currently four (4) major multizone air-handling units (AHU) serve the entire building. Two AHUs installed in the second floor mechanical room serve the second floor and first floor. The other two AHUs installed in the two mechanical rooms in the basement level provide air conditioning to the biomedical offices, labs and classrooms in the basement.

PREVIOUS HVAC MODIFICATIONS

Over the years, some modifications have been made to the building HVAC system to account for the operational and functional changes to the building.

The building was originally served by three AHUs. In the mid 1970s, a separate AHU was installed in the basement to provide air conditioning to the biomedical exam rooms, laboratories, and classrooms in the north side of basement.

In early 1980s, three direct expansion (DX) split systems with ceiling mounted fan coil units were installed in Room 2690 and Room 2686 to provide additional space cooling due to the addition of new computers to the rooms. There are also two 20-ton downflow chilled water air conditioning units and a 20-ton DX air conditioning unit installed in the server room (1601).

In the late 1990s, the 20-ton DX unit was replaced with a new 20-ton DX cooling only unit and the two 20-ton chilled water units were each replaced with new 26-ton chilled water units to meet the growing demand.

CURRENT CHALLENGES

Presently, the building is experiencing some thermal discomfort. For example, the temperature in the computer rooms 2686 and 2690 are very close to 90 degrees F when the computers are turned on. Room 2680 becomes very hot when occupied and computers on. Occupants have complained that some of the rooms are too cold, too hot, too much air flow, or too stuffy.

PRESENT PLANS

The university is planning to modify the spaces on the first floor and basement. In the basement, the existing biomedical area is planned to be modified to meet the rapid growth of student enrollment. On the first floor, the International Education Center is planned to convert into smaller offices. Any modifications of the existing facilities may require modifications of the existing HVAC systems.

STUDY SCOPE

UCR commissioned Goss Engineering, Inc (GEI) to determine the causes of thermal discomfort issues and to provide options to alleviate the current thermal discomfort issues as well as modifications to accommodate future occupant growth. This study included the following scope of work:

- Analyze existing and future building loads requirements
- Analyze the existing HVAC equipment, control and duct systems
- Analyze the current thermal discomfort in the building
- Develop options to resolve the issues
- Estimate budget construction costs for the recommended options, and
- Provide recommendations.

CHAPTER 3
EXISTING HVAC SYSTEMS

This chapter provides information on the existing HVAC system for the Statistics-Computer Building, which includes air handling units (AHU), exhaust fans, existing airflow, ductwork, heat exchanger, pumps, piping, fan-coil units, computer room air conditioning units, and controls.

Figure 3-1 to **Figure 3-6** at the end of this chapter show the existing HVAC floor plans.

AIR HANDLING UNITS

Currently four air-handling units provide heating, cooling, and ventilation to the building. These units are blow-through, constant volume, multi-zone air handling units containing outside air/return air mixing sections, 30% filters, supply fans, chilled and heating hot water coils, heating deck, cooling deck, and zone supply air mixing dampers. AH-1, AH-2 and AH-3 are single wall construction with liner insulation. AH-4 is double wall construction. These existing air handling units do not have a return for economizers.

As shown in **Figure 3-1** and **Figure 3-2**, AH-1 serves 3 temperature control zones, which include classroom, corridors and supporting areas for the Anatomy Lab in the basement south. The unit is located in the Mechanical Room B670 shown on Figure 3-2.

As shown in **Figure 3-3, Figure 3-4, and Figure 3-5,** AH-2 serves 9 temperature control zones, which includes offices, corridors and the server room on the first floor. The unit is located in the Mechanical Room 2590 on the second floor shown in Figure 3-5.

In **Figure 3-5** and **Figure 3-6,** AH-3 serves 13 temperature control zones, which includes offices, computer labs, corridors and classrooms on the second floor. The unit is located in the Mechanical Room 2590 on second floor shown in Figure 3-5.

As shown in **Figure 3-1,** AH-4 serves 8 temperature control zones, which includes the office, exam rooms, corridors, Anatomy Lab, conference room and classroom on the basement north. The unit is located in the Mechanical Room B625 in the basement.

AH-1, AH-2 and AH-3 were installed in mid 1970s when the building was constructed. AH-4 was installed in later the 1990s to replace the unit originally installed in mid the 1970s.

Table 3-1 below summarizes the existing air-handling units. The airflows and static pressures shown were obtained from available as-built information. As shown, the total building supply air was designed to be approximately 48,000 cfm. Detailed information is presented in **Table 3-2**.

Table 3-1: Existing Air Handling Unit Summary

Tag No.	Location	Area Served	Design fan Capacity (cfm @ in. w.g. TSP)	Motor HP	Overall Condition
AH-1	Room B670	South Basement	7,800 @ 2.125	7.5	Poor
AH-2	Room 2590	First Floor	14,575 @ 2.375	15	Poor
AH-3	Room 2590	Second Floor	16,350 @ 2.125	20	Poor
AH-4	Room B625	North Basement	9,130 @ 2.5	7.5	Good

Table 3-2: Existing Air Handling Unit Detailed Information

AHU ID		AH-1	AH-2	AH-3	AH-4
Area Served		BASEMENT NORTH	FIRST FLOOR	SECOND FLOOR	BASEMENT SOUTH
Make and Model		MCQUAY	MCQUAY	MCQUAY	HUNTAIR
TYPE		BLOW-THRU MULTI-ZONE	BLOW-THRU MULTI-ZONE	BLOW-THRU MULTI-ZONE	BLOW-THRU MULTI-ZONE
Design SA CFM		7,800	14,575	16,350	9,130
BLOWER TSP (IN WC)		2.125	2.375	2.125	2.500
MOTOR HP		7.5	15	20	7.5
OSA CFM		4,825	2,900	3,500	3,200
RA CFM		2,975	11,675	12,850	4,730
COOLING COIL	**ROW /FPI**	8/8	8/8	8/8	5/8
	CFM	7,070	13,225	15,250	7,800
	EAT (DB/WB)	81.3/65.2	81.4/64.2	86/68.4	85/67
	LAT (DB/WB)	53/51.8	53/51.2	53/51.8	55/54
	TOTAL MBH	270	476	616	310
	APD (IN WC)	1.125	1.25	1.06	1.05
	EWT (F)	43	43	43	44
	LWT (F)	54	57	59	54
	GPM	49	68	77	62
	WPD (FT WC)	3.9	10.5	8.4	10

Table 3-2: Existing Air Handling Unit Detailed Information (Contiuned…)

HEATING COIL	**ROW /FPI**	2/8	2/8	2/8	1/6
	CFM	7,270	13,030	15,510	8,200
	EAT (F)	65	65	61	55
	LAT (F)	78	86	84	85
	TOTAL MBH	100	300	390	260
	APD (IN WC)	0.7	0.7	0.7	0.27
	EWT (F)	160	160	160	160
	LWT (F)	140	140	140	140
	GPM	10	30	39	26
	WPD (FT WC)	1	2	2	2
FILTER		30%	30%	30%	30%
Approx. Installed Year		1974	1974	1974	1999
Overall Condition		POOR	POOR	POOR	GOOD
NOTE		1			2,3

Notes:

1. The OSA CFM and performance data is based on original design. OSA was adjusted to 2020 CFM in 1977.
2. The OSA CFM and performance data is based on original design. OSA was adjusted to 4,400 CFM in 1977.
3. VFD was installed for AH-4 to slow down fan during after-hours.

The actual fan total static pressure (TSP) was measured for each supply fan during GEI's field investigation. **Table 3-3** below summarizes the actual supply fan TSP in existing AHUs. The actual CFM is obtained from **Table 3-4** at the end of this chapter.

Table 3-3: Existing Air Handling Units Actual Performance Information

Tag No.	Location	Area Served	Actual Fan Capacity (cfm @ in. w.g.)
AH-1	Room B670	South Basement	6,170 @ 1.1
AH-2	Room 2590	First Floor	10,444 @ 1.52
AH-3	Room 2590	Second Floor	13,485 @ 1.8
AH-4	Room B625	North Basement	7,778 @ 1.48

The actual fan CFM and TSP is less than the design CFM and TSP.

Table 3-4 at the end of this chapter provides the areas and zones served by each air-handling unit.

AHU Supply Fans

The supply fans are squirrel cage type, belt driven, forward curved, and double inlet dual fans. For AH-1, AH-2, and AH-3, fan motors are mounted outside the unit while for AH-4, the motor is internal. The fans appear to be in poor condition. **Figure 3-1** below shows the old dusty dual squirrel cage fans in AH-2.

Figure 3-1: Existing Supply Fans in AH-2

The fact that the motors were mounted outside the air stream eliminates motor heat gains to the airflow, but increases air leakage through the fan shaft penetrations at the AHU casing.

Casing

The casing for AH-1, 2 and 3 appear to be in fair condition externally. However, the internal casing liner appear to be peeled off and the downstream cooling coil internal casing appears to be rusted. Some leakage were found through panel gaps and casing holes. The filters were installed upstream of the supply fans. Debris and dust inside the AHUs were blown through the duct to the occupied areas.

Outside Air Intake

The outside air (OSA) is obtained through exterior wall louvers on the second floor for AH-2 and AH-3. For AH-4, OSA is obtained through the OSA wells, which are covered at the top with mesh grills, on grade level for AH-4. For AH-1, OSA is obtained from the exterior wall louvers at the basement level.

Coils

The heating and cooling cools appear to be in fair condition. The drain pans and coil frames are rotted allowing air to bypass the coil.

The cooling coils are served with chilled water (CHW) from the campus physical plant. The heating coils are served with building heating-hot-water (HHW) that is generated in a heat exchanger located in Room B670 with high pressure steam (~65 psig) from the campus central plant.

Control Valves

The chilled and hot water control valves are three-way pneumatic control valves. The valves appear to be in fair condition at the time of GEI's field investigation.

Zone Dampers

Multiple temperature zone mixing dampers were installed at each AHU hot and cold deck discharge. A thermostat located in the typical space within the zone modulates the damper position (adjusts the cold deck and hot deck airflow ratio) to maintain space temperature. These zone dampers are pneumatic type and appear to be in fair condition.

Currently, 3 zone dampers were installed for AH-1, 9 zone dampers were installed for AH-2, 13 zone dampers were installed for AH-3, and 8 zone dampers were installed for AH-4.

Filters

The air handling units use 30% 2-inch thick throwaway filters.

Condition

Air-handling units AH-1, AH-2 and AH-3 are all now approximately 35 years old, and are in ***poor condition.*** As the expected median useful fan and coil service life is about 25 years (2007 ASHRAE HVAC Applications, Table 4, page 36.3, Akalin 1978), ***the AHU have exceeded their expected median service life*** by 10 years. The maintenance staff should be commended for their efforts in keeping these units running for this long.

However, AH-4 was installed in the 1990s and appears to be in good condition.

EXHAUST FANS

Three roof exhaust fans (EF) were installed to serve the building general and laboratory exhaust. EF-1 serves restroom exhaust. EF-2 and EF-3 provides exhaust for the Anatomy Lab (Room B632) in basement. **Table 3-5** below summarizes the existing roof exhaust fans.

Table 3-5: Existing Exhaust Fan Summary

Tag No.	Location	Area Served	Capacity (cfm @ in wc)	Motor HP	Type
EF-1	Roof	General exhaust	3,175 CFM @0.5	0.75	Roof Exhauster
EF-2	Roof	Anatomy Lab B632	3,800 CFM @ 1	1.5	Utility
EF-3	Roof	Anatomy Lab B632	2,000 CFM @ 1	0.75	Utility

EXISTING AIRFLOW

Table 3-4 at the end of this chapter provides the design and actual supply, return, and exhaust air flows for each occupied space in the building.

The measured space supply air flow was typically less than the design air flow, as well as the system outside air flow was more than the designed outside-air flow.

In a few cases the return air plenum has more pressure than the room causing reverse airflow.

DUCTWORK AND INSULATION

All the supply and return ducts are constructed with galvanized sheet metal. Ducts exposed in the mechanical room are internally insulated with duct liners. However, the ducts in the concealed ceiling space is externally insulated with fiberglass blanket. Periodical duct cleaning is essential to keep the ductwork interior surfaces clean and smooth to reduce debris from entering the occupied space and reduce air static pressure loss and fan energy.

STEAM-TO-HHW HEAT EXCHANGER

High pressure steam at 60 psig is supplied to the building Mechanical Room B670 from the central plant through the underground tunnel. The steam-to-HHW (heating hot water) heat exchanger was originally installed in mid 1970s. As the expected median useful heat exchanger service life is about 24 years (2007 ASHRAE HVAC Applications, Table 4, page 36.3, Akalin 1978), ***the original heat exchanger has exceeded its expected median service life*** by 10 years. **Table 3-6** below shows the specifications for the heat exchanger.

Table 3-6: Heat Exchanger Specifications

Location	Mechanical Room B670
Type	Shell and Tube
Manufacturer	Bell & Gossett
Model No.	SU 83-2
HHW Flow (gpm)	80
HHW Supply Temp (ºF)	180
HHW Return Temp (ºF)	140
Steam Pressure (psig)	65
Steam Temperature (ºF)	>300
Service	Building Heating
Year Installed	1974

PUMPS

The building has one HHW primary pump (P-3) and two chilled water (CHW) pumps (P-1 and P-2) in Room B670. The HHW primary pump circulates heating hot water in the primary loop to the AHUs. A secondary pump installed at the AHU circulates the HHW through heating coils in the AHU.

The chilled water pump serves as a booster pump to circulate chilled water, from the physical plant, to cooling coils in the AHUs. It appears that the two chilled water pumps were installed later and appear to be good condition.

The heating hot water pump appears to be the original pump and is very old. All three pumps operate at constant speed to provide cooling and heating for the building.

Table 3-7 below provides a summary of the pumps.

Table 3-7: Pump Specifications

Tag No.	P-1	P-2	P-3
Location	Room B670	Room B670	Room B670
Type	End Suction	End Suction	End Suction
Manufacturer	Paco	Paco	Unknown
Model No.	11-50955	11-30951	Unknown
Design Capacity (gpm @ ft. head)	290 @ 75	355 @ 75	105 @ 50
HP	10	10	3
VFD	No	No	No
Condition	Good	Good	Poor
Service	CHW	CHW	HHW - Primary
Year Installed	Unknown	Unknown	1974

The secondary heating hot water pump with fractional motor horsepower was installed for each heating coil at the AHUs and not listed herein.

GEI measured the actual water flow for each pump and AHU coil during the field investigation. **Table 3-8** below summarizes the measurements.

Table 3-8: Pump Actual Flow Measurement

Tag No.	P-1	P-2	P-3
Capacity (gpm)	200	130	103

As shown in Table 3-8, the total building chilled water flow is approximately 330 gpm (GPM from P-1 plus P-2 as two pumps are running at same time) and heating hot water is 103 gpm, which is almost the designed pump capacity.

PIPING

GEI noticed that some of the existing piping insulation appears to be asbestos. Abatement should be completed prior to any pipe demolition.

Figure 3-7 at the end of this chapter shows the building chilled water piping diagram.

Figure 3-8 at the end of this chapter shows the building heating hot water piping diagram.

FAN-COIL UNITS

In order to provide 24/7 continuous cooling for the computer labs, a direct expansion (DX) split system unit (including indoor fan coil unit and outdoor condensing unit) was installed in the ceiling space of Room 2684 and two DX units were installed in Room 2690 on the second floor.

Table 3-9 below summarizes the existing DX split systems.

Table 3-9: DX Split System

Tag No.	**FC-1/CU-1**	**FC-2/CU-2**	**FC-3/CU-3**
Location	Ceiling/Roof	Ceiling/Roof	Ceiling/Roof
Type	DX	DX	DX
Manufacturer	Unknown	Unknown	Unknown
Model No.	Unknown	Unknown	Unknown
Cooling Tons	0.5	1.5	0.5
Design CFM	200	550	200
Condition	Not working	Not Working	Not working
Service	Room 2690	Room 2684	Room 2684
Year Installed	1980	1988	1980

These fan-units supplied no air to the room when the room temperature was as high as 86 degree F during GEI's field investigation. A huge ice block was found at the fan-coil unit above the ceiling as shown in **Figure 3-9** below.

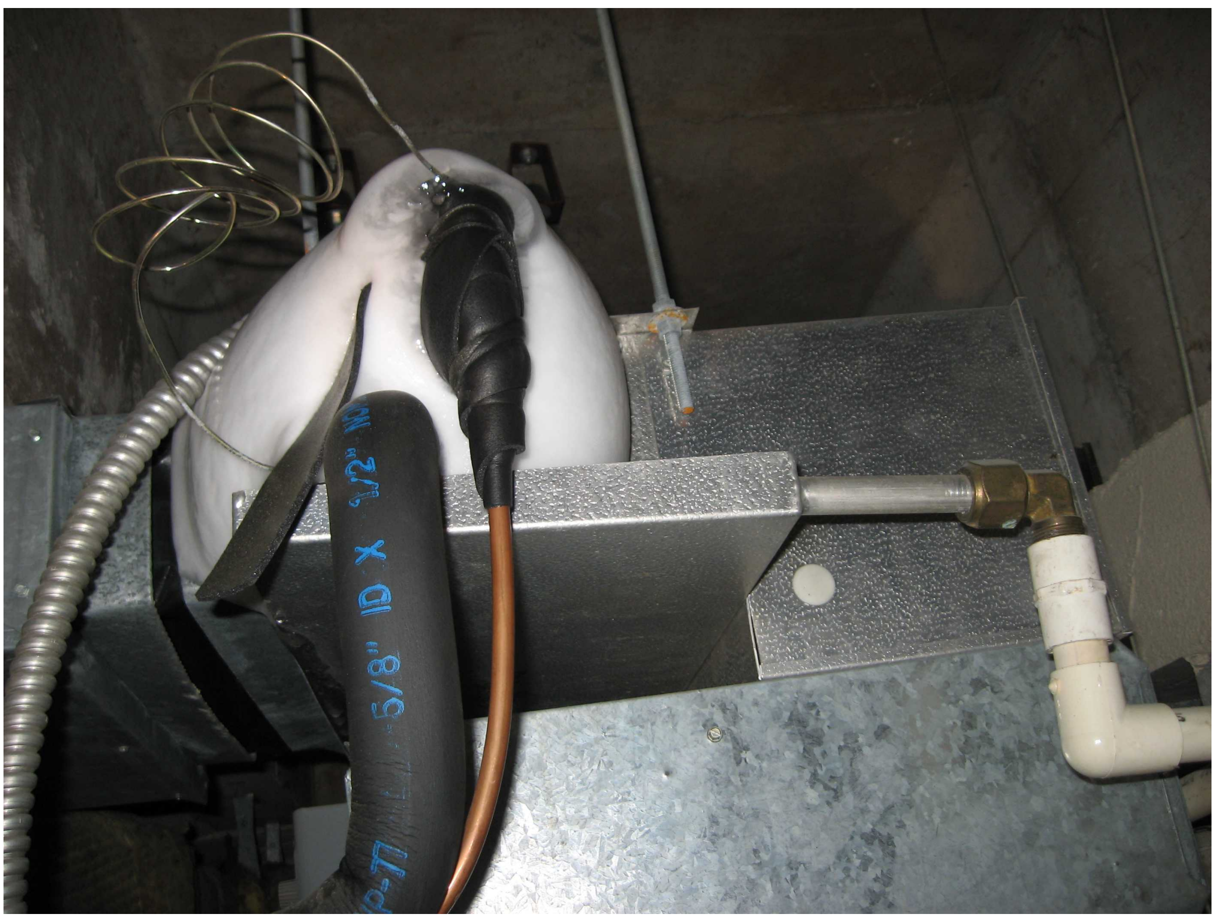

Figure 3-9: Ice block at Fan Coil Unit FCU-1 in Room 2690

COMPUTER ROOM AIR CONDITIONING UNITS

Three computer room air conditioning (CRAC) units were installed to serve the Server Room 1601. All the units are bottom discharge and top return units. The room supply air is discharged to the raised floor. **Table 3-10** below provides the specifications of the three CRAC units.

Table 3-10: Computer Room Air Conditioning Units

Tag No.	CRAC-1	CRAC-2	CRAC-3
Location	Room 1601	Room 1601	Room 1601
Type	Chilled Water	Chilled Water	DX
Manufacturer	DataAire	DataAire	DataAire
Model No.	DACD2631	DACD2631	DAAD2034
Cooling Tons	26	26	20
CFM	10,000	10,000	8,000
Chilled Water Temp	45 - 55	45-55	-
Chilled Water GPM	48	48	-
Condition	Fair	Fair	Fair
Service	Room 1601	Room 1601	Room 1601
Year Installed	Unknown	Unknown	Unknown

It appears that the room temperature is well controlled within the desired temperature range.

CONTROLS

The existing HVAC controls are stand-alone pneumatic controls. The control manufacturer for AH-1, 2 and 3 is unknown.

For AH-4, the pneumatic controls were provided by Johnson Controls. A variable frequency drive (VFD) was installed for AH-4, which operates on a 24/7 schedule to provide continuous ventilation for the areas including the Anatomy Lab. As an energy saving measure, the VFD slows down the fan to provide minimum required airflow when the building is unoccupied.

The existing temperature and pressure gauges are not operating correctly. Some temperature gauges show inconsistent temperature readings and some pressure gauges show no pressure readings across the pump while the pump is running.

CHAPTER 4

HVAC SYSTEM ANALYSIS

This chapter analyzes the existing HVAC system, including room air flows, existing ductwork, and existing piping. The existing system analysis identifies the problems with the existing HVAC system. The existing HVAC system is described in Chapter 3.

SYSTEM AIRFLOW

This paragraph presents the existing HVAC system airflow comparison with the designed, required (or calculated) and actual airflow.

Required HVAC System Air Flow

The required airflow for the existing system is determined by the required system cooling and heating load. The HVAC cooling and heating load for a typical system is determined by the heat gains through the space enclosure such as walls, windows, roof, as well as occupants, outside air ventilation, lighting, and equipment (i.e. computers, etc).

California Title-24 climate zone for the City of Riverside is 10. The weather is hot in the summer and mild in the winter. Per California Title-24, the 0.1% summer design outdoor temperature used for a critical facility (such as AH-1 and AH-4 serving labs) is 110 degrees F dry-bulb and coincident 75 degrees F wet-bulb, and 0.5% summer design outdoor temperature for non-critical facility (such as AH-2 and AH-3 systems) is 104 degree F dry-bulb and coincident 69 degree F wet-bulb. For both facilities, the winter minimum temperature is 34 degrees F.

In addition to the temperatures described above, the following criteria, based on governing code requirements (for occupancy, ventilation, temperature, etc), equipment nameplate data (computers, etc), and industry-wide used defaults (when actual load is not available), were used as a basis for each system load calculation:

- Ventilation: 20 cfm per person or 0.15 cfm per square foot of gross floor area, whichever is larger.
- Lighting load: 1.5 watts per square foot for offices.
- Occupant number: counting seats or averaged 100 square feet per person, whichever is larger. 250 btu per hour for sensible and latent heat gain respectively.
- Equipment (computer, printer, and etc) heat gain: counting computer quantity or 2 watts per square foot of enclosed space floor area, whichever is larger.
- Design indoor temperature: summer 75 F and winter 70 F for typical office areas; 72 F for typical computer labs in both summer and winter.

- SA temperature at 55 F is used for CFM calculations.

GEI used the Trane Trace 700 load calculation software for this study to estimate the building HVAC system cooling and heating load requirements. The following building enclosure information, based on GEI's field investigation and as-built drawings, was used for system load calculations:

- 4.5-inch thick concrete roof with R11 rigid insulation
- 10-inch thick brick exterior wall without insulation
- Uninsulated clear window without shading– 1.1 btuh/sqft per degree F for "U" factor, 0.8 for shading coefficient (SC).

Table 4-1 below summarizes the HVAC system/space cooling load calculation output. Detailed calculation outputs are provided in **Appendix A** at the end of this report.

Table 4-1: HVAC System Air Flow and Water Flow Calculated Requirement

Tag No.	Location	Area Served	Required CFM @ 55 F supply air temp	Required Chilled Water GPM @ 15 F delta-T
AH-1	Room B670	South Basement	6,840	45
AH-2	Room 2590	First Floor	10,780	32
AH-3	Room 2590	Second Floor	15,710	53
AH-4	Room B625	North Basement	8,788	31

Airflow Comparison

Due to lack of the HVAC system air balancing report, in early January 2008, GEI measured the actual supply airflow rate to the all the spaces by using a digital flow hood. The flow hood has a +/- 3% accuracy. **Table 3-4** in chapter 3 summarizes and compares the measured supply airflow rate to the rooms versus the design flow rate. **Table 4-2** below presents the calculated, designed and actual system airflow comparison. All the calculated airflow rates were based on the 55 degree F supply air temperature.

Table 4-2: HVAC System Air Flow Comparison

Tag No.	Location	Actual CFM	Required CFM @ 55 F supply air temp	Design CFM
AH-1	Room B670	6,170	6,840	7,800
AH-2	Room 2590	10,444	10,780	14,575
AH-3	Room 2590	13,485	15,710	16,350
AH-4	Room B625	7,778	8,788	9,130

As shown in **Table 4-2**, except for AH-2, the actual supply air rates from other system are 10 to 20 percent less than the calculated rates. For AH-2, the actual CFM is within the 5% range and appears to be reasonable.

PIPING SYSTEM

The Statistics-Computer Building is served by 6-inch chilled water supply and return pipes from the Central Plant. The calculated total chilled water required is 161 gpm for the four AHUs, based on supply/return at 45/60 degree F, shown in Table 4-1. The actual total pump capacity is approximately 330 gpm for chilled water (including CRAC unit 96 gpm total) and 103 gpm for heating hot water. The existing chilled water and heating hot water pumps and piping are adequate to serve the load.

THERMAL CHALLENGES ANALYSIS

GEI believes that the following factors listed below are the cause of the building thermal discomfort issues:

- Existing HVAC system lowered cooling and heating capacity than design.
- Lack of air balancing and duct cleaning.
- Improper return-air path
- Excessive outside air
- Existing old and less responsive pneumatic controls
- Failed DX split system
- Improper zoning and locations of thermostats

The above items are described below.

Existing HVAC System Lowered Cooling and Heating Capacity than Design. The existing coils in AH-1, AH-2 and AH-3 are very old and have less heat transfer capacities than as designed. During the summer and winter, the coil leaving air temperature set point is difficult to maintain. Also, AH-1, AH-3 and AH-4 deliver less than required airflow to the occupied space. Therefore, the space temperature cannot be maintained at design ranges.

Lack of Air Balancing and Duct Cleaning Although the current total airflow supply to the spaces are adequate for system AH-2, the existing supply air was not properly balanced for each individual occupied space. Some rooms have more supply air than needed while other rooms have less supply air than needed. Some room function has been changed while the supply air had never been re-balanced to meet the new load requirement. As a result, thermal discomfort problem occurs in these rooms.

Also, it appears that the existing duct system was never cleaned. The duct systems were installed more than 30 years ago. Dust and debris build-up creates extra air pressure drop (resistance) along the ductwork and reduces the supply air flow.

Improper Return-Air Path Existing return corridor ceiling space is used as a return air plenum. Return air was designed to be transferred through ductwork from one room to the ceiling space of the adjacent room, and then transferred to the corridor ceiling space through a fire damper protected corridor wall. Some return air is transferred more than 3 times in series from room to room. For example, return air is designed to be transferred from Room 2066 through ceiling the grille to its ceiling space, then in series to the ceiling space of Room 2604 and 2608 then through the fire damper-protected opening to the corridor ceiling space.

While the existing return-air paths to the plenum seems to be operable at first glance, the actual existing RA path of travel has a very high static pressure (SP) required to move air from Room 2600 to 2604 to 2608 then to the corridor ceiling space is calculated and shown in **Appendix B**. As indicated, a minimum SP is 0.15-in water column (W.C.). The plenum cannot be maintained at such a negative pressure (the T-bar ceiling is not sealed air tight) and therefore, the air is never completely returned following the existing RA paths. Instead, only a small part of the room air is returned to the system, resulting in room over-pressurization. On the other hand, the return air to the AHU includes space return air and outside air.

Excessive Outside Air The existing system has excessive OSA due to minimum return air and lack of system air balancing. Too much OSA increases the coil heating and cooling load causing the coil leaving-air-temperature to be difficult to control within the preset range.

Existing Old and Less Responsive Pneumatic Controls The existing controls are all out dated pneumatic controls and less responsive. The space mounted thermostat modulates the zone damper at the unit discharge through a pneumatic signal to control room temperature. It takes a while to communicate between the damper and the thermostat. Therefore, the space temperature is nearly impossible to control within the required range unless the space load is relatively stable.

Failed DX Split Systems Three direct expansion split systems currently serving Room 2686 and 2690 (computer labs) are not working properly. These units are in very bad condition and appear to be in already-failed condition. The dedicated space temperature sensors (not the wall mounted pneumatic thermostats which control zone dampers), which are installed in the house-air ceiling return grilles, fail to energize the split system for cooling causing the room temperature to reach as high as 85 degree F.

Improper Zoning and Locations of Thermostats Some temperature control zones include many spaces have only one thermostat in one of the rooms. Due to the various cooling and heating load profiles among these rooms, the temperature of the room with the thermostat is under control while the other rooms, with different load profiles, experience thermal discomfort. For example, Room 1626A, 1626B, 1626C (3 offices) share a zone with Room 1626D (conference room). Room 1626D is a conference room with a different cooling load profile than basic office areas.

CHAPTER 5

PROPOSED HVAC SYSTEM MODIFICATIONS

This chapter discusses the proposed HVAC system modifications to resolve the current thermal discomfort issues in the building.

PROPOSED HVAC SYSTEM MODIFICATIONS

As discussed in **Chapter 4**, the existing HVAC system is experiencing inadequate cooling and heating, out dated controls, lack of balancing, excessive OSA, and space over-pressurization. GEI proposed the following modifications to resolve the current thermal discomfort issues:

- Replace existing heating and cooling coils and supply fans with larger capacity in AH-1, AH-2 and AH-3
- Rebalance OSA, RA and SA to meet room loads
- Completely clean existing ductwork
- Eliminate RA transfer paths and install fire-ceiling RA plenum or return duct
- Replace existing controls with direct digital controls (DDC)
- Replace Failed DX split systems with new

The following paragraphs describe the modifications in more details.

Replace Existing Heating and Cooling Coils and Supply Fans with Larger Capacity in AH-1, AH-2 and AH-3

As discussed in Chapter 4, the existing fans and coils are very old, have lower capacity, and should be replaced with new. GEI proposed three options for this modification.

- **Option 1 - Replace existing coils and fans only with new.** New fans are proposed to be more energy efficient and have larger airflow capacity. The fan motors are proposed to be installed inside the air handling units to prevent air leakage through fan shaft penetrations. With new cooling and heating coils, the heat transfer will be improved and the coil leaving air temperature can be maintained at the desired range. As the existing unit casings are very old and leaking air, **GEI does not recommend this option**. This option is presented here is to show this as a basis for option comparison purposes.

- **Option 2 - Replace Existing AHUs with new.** As described in Chapter 3, the existing casings have air leakage and interior casing liners are peeled off. New custom-made field-built-up AHUs are proposed to have double wall construction with perforated metal liner instead of existing fiberglass liners. Compared with option 1, this option includes the replacement of the entire unit and therefore cost more than option 1. However, the advantages includes more energy savings due to less or no air leakage and better casing insulation.

- **Option 3 - Replace Existing AH-1, AH-2 and AH-3 with New Cooling Only Units and Install Terminal Zone Reheat Coils.** The supply air temperature is proposed to be maintained at 55 degree F prior to the terminal heating hot water reheat coils. The space thermostat then modulates the reheat coil control valve to maintain the space temperature. Compared with option 2, this option have the following advantages:

    1. Zoning flexibility. It is impossible to add new duct zones to the existing AH system if more zones are added. However, with reheat coil option and some ductwork modifications, additional zones can be added to the existing ductwork. This is best suited for the future room function changes or current zoning addition.

    2. Better temperature controls. Space thermostats modulate the reheat coil valves to control room temperature. Temperature controls are more responsive.

    The disadvantages are high construction cost. AH-4 is in good condition and is not proposed to be replaced.

    GEI recommends Option 3.

    Figure 5-1shows the proposed AH-1 system floor plan.

    Figure 5-2 and Figure 5-3 show the proposed AH-2 system floor plan.

    Figure 5-4 and Figure 5-5 show the proposed AH-3 system floor plan.

Rebalance OSA and SA to Meet Room Load

The existing building OSA and supply air to the occupied spaces is not properly balanced as described in Chapter 4. The space supply air should be rebalanced to meet the space load requirements. The building OSA should be reset to the minimum requirements set by the 2007 California Mechanical Code and Title-24.

Completely Clean Existing Ductwork

The existing building supply and return duct and diffusers should be completely cleaned.

Eliminate RA Transfer Paths and Install Fire-Ceiling RA Plenum or Return Duct

The existing return air transfer duct is proposed to be removed to eliminate the return/transfer air paths. Two options were developed to provide the required air return.

- **Option 1 – Install new 2-hour fire-rated ceiling on the first and second floor corridor areas.** The existing corridor walls are full height fire-rated wall. The corridor ceiling is a typical non-rated T-bar ceiling. The corridor ceiling space currently serves as a return-air plenum. The existing return-air enters the plenum through the corridor wall openings protected with fire dampers. GEI proposes a 2-hour rated hard ceiling installed in the corridor to make the corridor a fire exit tunnel. The corridor ceiling space can be used as a return air plenum. The openings on the corridor walls do not require fire protection. Each room can have a direct opening to the ceiling return plenum instead of passing through a return/transfer air path. By eliminating the paths, building pressurization and OSA leakage problems may be resolved.

  There is no need for a 2-hour fire-rated ceiling for the area served by AH-1 and AH-4 in the basement.

  Figure 5-2 and 5-3 shows proposed first floor plan. **Figure 5-4 and 5-5** shows proposed second floor plan.

- **Option 2 – Install new return duct to each space** To remove the transfer air paths, return air ducts to each room can be installed. However, the very limited existing corridor ceiling space (approximately 18 inches between bottom of structure and ceiling), existing ceiling supply ducts, electrical conduits and pipes makes the new duct installation very difficult and virtually impossible. **Figure 5-6** shows first floor plan. **Figure 5-7** shows second floor plan. **GEI does not recommend this option.**

Replace Existing Controls with Direct Digital Controls (DDC)

The existing pneumatic controls are too old and out dated. GEI proposed to replace the existing controls with new DDC controls. The DDC is very responsive and easy to monitor and adjust.

Replace Failed DX Split Systems with New Chilled Water Fan Coil Units

The existing three DX split systems are not working properly. GEI proposed to replace the three units with new chilled water units with the cooling capacity to meet the current load. When larger delta-T cooling coils are installed to replace the existing coils in the AHUs, less chilled waterflow (in gpm) is required and therefore, existing pipe size is adequate.

Figure 5-4 and **Figure 5-5** show chilled water unit locations and piping routes.

CHAPTER 6

OTHER FINDINGS AND PROPOSED MODIFICATIONS

This chapter discusses other findings related to potential energy conservation during GEI's field investigation and proposed modifications for energy savings.

CHILLED WATER 3-WAY CONTROL VALVES

The existing 4" chilled water control valves (one for each AHU) are all 3-way mixing control valves. The two chilled water pumps are running at constant speed to supply chilled water. The 3-way chilled water control valves should be avoided. The disadvantages for the 3-way valves are as follows:

- Constant speed pumps (each with 10 hp motor) consumes a constant amount of energy even at partial load which occur most of time.
- The mixing valves decrease the chilled water return temperature at partial load. The higher chilled water return temperature is, the more efficient the thermal storage tank in the Physical Plant would be.

LOW CHILLED AND HEATING HOT WATER TEMPERATURE DIFFERENTIAL

The existing design chilled and heating hot water temperature difference appears to be very low. The chilled water temperature difference was designed to be ranging from 10 to 16 degree F and the heating hot water temperature difference was designed to be approximately 20 degree F. Lower temperature differential across coils results in larger pumps, motors and pipes.

HEATING HOT WATER PIPING

The existing HHW piping system is a primary-secondary system. The primary pump P-3 is always running at constant speed to supply water to the AHUs. A secondary small pump is installed at the AHU to circulate HHW to heating coil when heating is required. As the HHW is generated by a steam-to-water heat exchanger (not a boiler which requires minimum 120 degree F return water temperature to avoid condensation), a constant water flow in the loop is unnecessary and wasting energy.

ECONOMIZER

The existing HVAC system has a constant return and outside air system. No modulating dampers (economizer) were installed in the return and outside air duct. When outside temperature is between 55 and 75 degree F, the space air (usually more than 75 degree F in summer) is still returned to the AHUs and wasting chiller energy.

RECOMMENDATIONS

GEI recommended the following modification for energy conservations:

- Replace existing 3-way valves with new 2-way valves
- Install variable frequency drives (VFD) on the chilled and heating hot water primary pumps. At partial load, the 2-way control valves close and water flow is reduced. The VFDs then slow down the chilled and heating hot water pumps and energy is saved.
- Remove all secondary heating hot water pumps.
- Install economizers for all air handling units. Install roof exhaust fans to relieve building pressure during economizer cycles
- Select cooling and heating coils with large temperature differential. Use minimum of 20 degree F temperature differential for the chilled water coils to improve thermal storage efficiency and reduce pump energy consumption. Minimum of 60 degree F temperature differential should be used for heating coil selections. Compared to existing 20-degree F, the pump energy is reduced by at least 65%.

CHAPTER 7

BUDGET CONSTRUCTION COST ESTIMATE

This chapter describes the estimated budget construction cost for the proposed HVAC modifications options described in **Chapter 5**.

BUDGET CONSTRUCTION COSTS

The estimated budget construction costs for the Statistics-Computer Building HVAC Modifications include the following work:

- Mechanical Work. In general the mechanical work includes the demolition and installation of the existing equipment and ductwork.

- Electrical Work. All work associated with conveying electrical power to the new equipment.

- Structural Work. All structural work associated with supporting new equipment.

In addition to the direct costs associated with the above-mentioned work the construction costs include the following:

- 7.75% sales tax on the cost of all materials.
- 5% General Requirements on the total direct construction cost, including sales tax.
- 20% contingency on the total direct construction cost, including sales tax and General Requirements.
- 15% of construction cost (direct construction cost, sales tax, General Requirements, contingency, midpoint escalation, and insurance and bond) for contractor's overhead and profit.

Table 7-1 at the end of the chapter provides a detailed budget construction cost estimate for Option 2 – Replace existing AH-1, AH-2 and AH-3 with new.

Table 7-2 at the end of the chapter provides a detailed budget construction cost estimate for Option 3 – Replace existing AH-1, AH-2 and AH-3 with new cooling only units and terminal reheat coils.

The estimated total budget construction cost estimate for Option 2 is approximately **$930,000**.

The estimated total budget construction cost estimate for Option 3 is approximately **$1,100,000**.

GEI recommends adding 20% of the construction cost for engineering (10%), construction admin (5%), owner construction contingency (4%), and testing (1%) to cover project costs.

APPENDIX A

Load Calculations

APPENDIX B

Transfer Duct Path Static Pressure Calculations