Analysis of Raised Access Floor
vs.
Conventional Distribution

30 October, 2003

Command and Control Center
Fort Stewart, Georgia

CONTRACT NO: DACA21-03-R-0039

U. S. Army Corps of Engineers
Savannah District
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EXECUTIVE SUMMARY

Introduction:

At the briefing at Ft. Stewart on 10/7/03 RTKL described the benefits of a raised access floor with underfloor air distribution, communications and power distribution as an integrated sustainable design solution. These benefits include flexibility in reconfiguration of workstation layouts, easy connectivity of power and data, increased ceiling heights and improved daylighting.

It was agreed at this meeting that we should proceed with the raised floor concept contingent upon validating costs within overall project budget at the 35% design.

This document responds to that request and provides the following:

1. Benefits of raised access floor
2. First Costs: analysis of comparative costs – conventional vs. under floor distribution
3. Operating Costs: analysis of cost savings over time
4. Recommendations

First Costs:

The cost model on Page 4 includes quantities and associated costs for access floor and conventional floor scenarios based on the concept drawings. Pricing obtained from a local supplier indicates the costs of the access floor range from $5.75 to $6.25 installed cost. With other factors considered, such as floor to floor height and Mechanical/Electrical/Communications distribution, our cost model indicates that there is essentially no premium imposed by the access floor design. Even if a $7.00/SF cost is assumed, the resulting premium will be amortized within a five year period due to lower operating costs (see below).

Access floor also allows a reduction in the cost of systems furniture because power and data can be accessed directly through floor boxes in lieu of running it through the systems furniture. Comparative costs were developed indicating a potential savings of $129,450 by using non-powered systems furniture.

Operating Costs:

This comparative analysis is based on a HVAC computer model of the proposed building systems. Contributing factors, some of which contribute directly to energy savings and some only to fan (energy) savings, are discussed in the report:

- Free cooling
- Internal loads
- Underfloor air distribution credit
- Building envelope loads
- Sustainability

Reduced HVAC operating cost with an underfloor system provides a savings of $21,230 per year over a conventional building design and distribution system.

BENEFITS OF RAISED ACCESS FLOOR

General:

- Integrated Raised Access Floor (RAF) - floor to floor = 14'-0"
- Overhead conventional - floor to floor = 14'-8"
- Increased ceiling height
- Improved daylighting to interior spaces due to higher windows
- Ease of furniture reconfiguration
- Unencumbered planning modules
- SPiRiT "gold" requirement
- Potential savings for non-powered system furniture vs. powered furniture

HVAC and Ventilation:

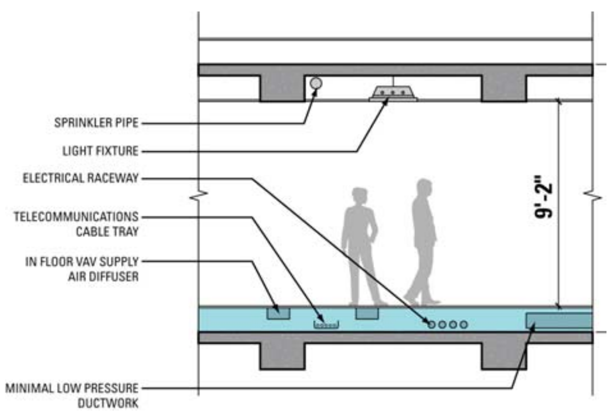
- Enhanced personal comfort – with under floor air distribution, people can adjust air flows
- Adjustable temperature sensors
- Ventilation effectiveness better with under floor air
- Increased economizer lowers operating costs
- Multiple zoning capability

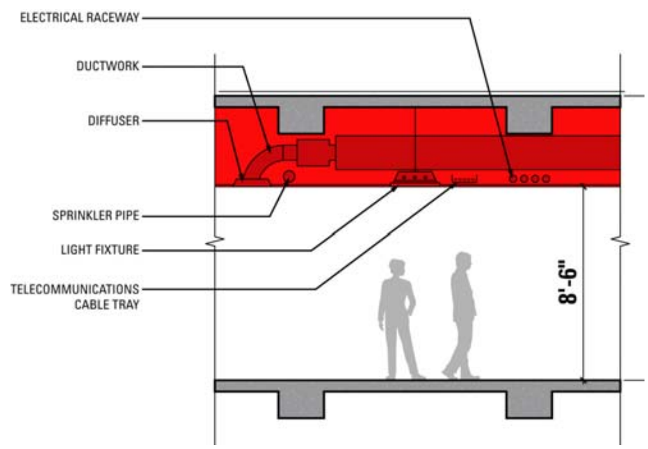
Electrical:

- Underfloor power distribution maximizes flexibility – furniture is not restricted

Telecommunication and Data:

- RAF solution for voice & data distribution is gold standard for flexibility
- Plug-and-play electrical and data distribution





FIRST COSTS:

Analysis of comparative costs – conventional vs. under floor distribution

First Costs – Raised access floor:

The cost model on the following page includes quantities and associated costs for access floor and conventional floor scenarios based on the concept drawings. Pricing obtained from a local supplier indicates the costs of the access floor range from $5.75 to $6.25 installed cost. With other factors considered, such as floor to floor height and Mechanical/Electrical/Communications distribution, our cost model indicates that there is essentially no premium imposed by the access floor design. Even if a $7.00/SF cost is assumed, the resulting premium will be amortized within a five year period due to lower operating costs.

Marked up Subcontractor installed costs:

	2nd Floor	All Floors
	25,000 SF	80,000 SF
Tate 1000 Series:	$5.75 SF	$5.25 SF
Tate 1250 Series:	$6.25 SF	$5.75 SF
Stringer system	.50c /SF	.50c /SF

Cost data obtained from:
Center Brothers Inc.
Jacksonville
Contact: Philip May (904)733-2820

First Costs – Systems Furniture:

Access floor allows a reduction in the cost of systems furniture because power and data can be accessed through recessed floor boxes in lieu of running it through the systems furniture.

Comparative cost for 3 options were developed:
This indicates a potential savings of approximately $100,000 between Option 1 and Option 3. This takes into consideration the cost of recessed floor boxes in raised floor (option 3).

		Cost per workstation	Total for 312 workstations
Option 1	with powered spline wall	$7,837	$2,445,114
Option 2	with powered spline wall and wing walls	$8,294	$2,587,728
Option 3	with no power in furniture system (raised access floor solution)	$7,422	$2,315,664

Note: Estimated cost totals above are approximate and are used for comparative purposes only. Total costs do not include office or conference furniture etc.

Refer to attached System Furniture diagrams for detail of typical workstation layout used in this pricing study.

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ACCESS FLOOR COST STUDY

Item	Access floor cost		Building Without Access Floor	Building with Access Floor (All Levels)	Difference (assuming access floor)	Cost $/GSF	Building with Access Floor (2nd Floor Only)
Floor to floor height increase of 8":							
Concrete column extension			$ 29,465		$ (29,465)	0.28	$ 29,465
Precast concrete panel increase			$ 9,618		$ (9,618)	0.09	$ 9,618
Facebrick wall increase			$ 11,520		$ (11,520)	0.11	$ 11,520
Exterior wall backing increase			$ 16,219		$ (16,219)	0.16	$ 16,219
Window increase			$ 33,350		$ (33,350)	0.32	$ 33,350
Interior partition height increase			$ 27,773		$ (27,773)	0.27	$ 27,773
Access floor used:							
Raised Access Floor (Tate 1000 Series) 18" high with stringers	**$ 5.75**	SF		$ 490,015	$ 490,015	-5.71	$ 163,338
Core area raised concrete floor				$ 18,480	$ 18,480	-0.18	$ 18,480
Mechanical differences:							
Ductwork quantity and installation increase:			$ 277,305		$ (277,305)	2.65	$ 277,305
Insulation required on overhead ductwork:			$ 63,501		$ (63,501)	0.61	$ 63,501
Penetration sealing more stringent:				$ 10,453	$ 10,453	-0.10	
Other overhead installation premiums:			$ 4,181		$ (4,181)	0.04	$ 4,181
Electrical differences:							
Distribution increase (busduct l.f):			$ 1,440		$ (1,440)	0.01	$ 950
Lighting overhead installation premiums (lower clg ht):			$ 12,800		$ (12,800)	0.12	$ 12,800
Power overhead installation premiums (reduced overhead work):			$ 9,600		$ (9,600)	0.09	$ 6,336
Systems overhead installation premiums (reduced overhead work):			$ 29,188		$ (29,188)	0.28	$ 29,188
SUBTOTAL			**$ 525,960**	**$ 518,948**	**$ (7,012)**		**$ 704,025**
Area of Access Floor (2nd Floor):	28,407	SF					
Area of Access Floor (All Floors):	85,220	SF					
Subtotal - 1250 Series access floor (with stringers) cost per S.F:	**$ 6.25**	/SF	**$ 525,960**	**$ 561,558**	$ 35,598		**$ 718,228**
Subtotal if access floor cost per S.F is:	**$ 7.00**	/SF	**$ 525,960**	**$ 625,473**	$ 99,513		**$ 739,533**

1. OPERATING COSTS:

Analysis of cost savings over time…

Mechanical Systems

Free cooling:
The underfloor system delivers air at 61°F reset to 63°F during winter as compared to 55°F for a conventional overhead distribution system. So the underfloor system is able to take advantage of the additional hours available in a typical year as illustrated on page 11, using Carrier HVAC program. When the temperature is below 63°F energy saving and operating costs are achieved by turning the chillers, cooling towers and pumps off. It is reflected in the cooling costs on page 7.

Internal Loads:
In an underfloor distribution system, since the lighting fixture is located above the breathing zone, only 20% of the overhead lighting load is considered as part of the space load, 80% of the lighting load goes directly to the cooling coil through the return air. All of the sensible heat generated by people and equipment is still considered as part of the Space Sensible Load, because they all occur in the breathing zone or the first 6' of the space. This is reflected in HVAC loads on page 8 and 9.

Underfloor air distribution credit:
Since the supply air temperature in the supply plenum for underfloor system is 60° - 65°F air, the space temperature directly above the carpeting is normally 72°- 73°F, some heat from the space will be transferred by conduction through the floor to the raised access plenum directly. This portion of heat does not see Space Sensible Load and may be deleted from the space sensible load. Testing has shown that this is between 0.6 and 1.0 watt per square foot. RTKL used 0.6 watts per square foot credit in space sensible. This load is seen by the cooling coil at the AHU.

Building Envelope Loads
With an overhead distribution system, all of the skin loads typically become part of the space sensible load but with an underfloor system, the solar radiation that penetrates the space warms the raised access floor. A portion of the solar radiated heat becomes a space load and the other portion conducts into the supply air plenum. The portion that conducts into the supply air plenum does not become part of the space load resulting in reduced fan CFM to the space.

The underfloor distribution system only conditions the breathing zone, or the first 6' of the space, some of the skin loads (above 6' breathing space) can be transferred from the space air load to the return air. Generally 60% of the skin load is accounted for in the space and the remaining 40% is transferred directly into the return air (back to the cooling coil) as opposed to overhead distribution system where almost 100% of the load is seen by the space. This is reflected in HVAC loads on page 8 and 9.

Sustainability:
Underfloor distribution system helps in providing a sustainable building design in the following way:

a. Reduced life cycle cost, associated with reduced HVAC and workstation churn rate:
   Another factor that plays a role is the churn rate for HVAC, every year some of HVAC reconfigurations are required to accommodate new and relocated workstations, maintaining good comfort conditions. In underfloor systems these changes can be quickly and easily accomplished, thereby saving HVAC churn cost as compared to a conventional overhead system. This is not factored in the analysis.

b. Productivity gains:
There are number of studies tying indoor air quality to productivity and absenteeism, it suffices to say that underfloor system provides improved ventilation effectiveness and an increase in the total amount of outside air supplied to the space in a year, contributing to productivity gains and employee absenteeism improvement. Again this is not factored in the analysis.

c. Reduced energy use and cost:
There is reduced energy use and reduced cost, as indicated above from following:
- increased free cooling
- increased chiller efficiency from higher chilled water temperatures
- reduced fan energy due to reduced ductwork
- increased cooling temperature setpoints due to occupant choice of adaptive comfort control.

HVAC Computer model:
As of to date, there is no software program that accurately models underfloor system, which requires computational fluids dynamics to model the convective effects of air moving up and displacement of air. The available software programs, use a "well mixed air mass throughout the building" approach and do not account for stratification which is the most significant feature of underfloor displacement systems. For this analysis, Carrier HAP program was used to model the above factors.

UNDERFLOOR SYSTEM

Table 1. Annual Costs

Component	Operating Cost ($)
Air System Fans	30,935
Cooling	65,937
Heating	0
Pumps	5,409
Cooling Tower Fans	13,787
HVAC Sub-Total	**116,068**
Lights	223,340
Electric Equipment	216,428
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**439,768**
Grand Total	**555,835**

Table 2. Annual Cost per Unit Floor Area

Component	Operating Cost ($/ft²)
Air System Fans	0.296
Cooling	0.630
Heating	0.000
Pumps	0.052
Cooling Tower Fans	0.132
HVAC Sub-Total	**1.109**
Lights	2.133
Electric Equipment	2.067
Misc. Electric	0.000
Misc. Fuel Use	0.000
Non-HVAC Sub-Total	**4.200**
Grand Total	**5.309**
Gross Floor Area (ft²)	104700.0
Conditioned Floor Area (ft²)	104700.0

Note: Values in this table are calculated using the Gross Floor Area.

CONVENTIONAL OVERHEAD SYSTEM

Table 1. Annual Costs

Component	Operating Cost ($)
Air System Fans	36,418
Cooling	78,095
Heating	0
Pumps	6,381
Cooling Tower Fans	16,406
HVAC Sub-Total	**137,299**
Lights	223,340
Electric Equipment	216,428
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**439,768**
Grand Total	**577,067**

Table 2. Annual Cost per Unit Floor Area

Component	Operating Cost ($/ft²)
Air System Fans	0.348
Cooling	0.746
Heating	0.000
Pumps	0.061
Cooling Tower Fans	0.157
HVAC Sub-Total	**1.311**
Lights	2.133
Electric Equipment	2.067
Misc. Electric	0.000
Misc. Fuel Use	0.000
Non-HVAC Sub-Total	**4.200**
Grand Total	**5.512**
Gross Floor Area (ft²)	104700.0
Conditioned Floor Area (ft²)	104700.0

Note: Values in this table are calculated using the Gross Floor Area.

UNDERFLOOR SYSTEM: HVAC LOADS

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Aug 1500 COOLING OA DB / WB 95.0 °F / 79.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 26.0 °F / 21.8 °F		
ZONE LOADS	**Details**	**Sensible (BTU/hr)**	**Latent (BTU/hr)**	**Details**	**Sensible (BTU/hr)**	**Latent (BTU/hr)**
Window & Skylight Solar Loads	9258 ft²	337276	-	9258 ft²	-	-
Wall Transmission	21630 ft²	0	-	21630 ft²	42591	-
Roof Transmission	33100 ft²	0	-	33100 ft²	58242	-
Window Transmission	9258 ft²	88998	-	9258 ft²	232191	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	10260 ft²	0	-	10260 ft²	4034	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	196941 W	74437	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	188460 W	581842	-	0	0	-
People	663	108604	135935	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	30%	101117	0
>> Total Zone Loads	**-**	**1191156**	**135935**	**-**	**438174**	**0**
Zone Conditioning	-	1377588	135935	-	127078	0
Plenum Wall Load	100%	19834	-	0	0	-
Plenum Roof Load	100%	51855	-	0	0	-
Plenum Lighting Load	86%	577887	-	0	0	-
Return Fan Load	76723 CFM	0	-	16633 CFM	0	-
Ventilation Load	13262 CFM	135712	471256	13262 CFM	487785	0
Supply Fan Load	76723 CFM	126497	-	16633 CFM	-15177	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**2289374**	**607191**	**-**	**599686**	**0**
Central Cooling Coil	-	2289375	607415	-	0	0
Zone Heating Unit Coils	-	0	-	-	599559	-
>> Total Conditioning	**-**	**2289375**	**607415**	**-**	**599559**	**0**
Key:	**Positive values are clg loads Negative values are htg loads**			**Positive values are htg loads Negative values are clg loads**		

CONVENTIONAL OVERHEAD SYSTEM: HVAC LOADS

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Aug 1500 COOLING OA DB / WB 95.0 °F / 79.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 26.0 °F / 21.8 °F		
ZONE LOADS	**Details**	**Sensible (BTU/hr)**	**Latent (BTU/hr)**	**Details**	**Sensible (BTU/hr)**	**Latent (BTU/hr)**
Window & Skylight Solar Loads	9258 ft²	337276	-	9258 ft²	-	-
Wall Transmission	21630 ft²	19834	-	21630 ft²	42591	-
Roof Transmission	33100 ft²	0	-	33100 ft²	58242	-
Window Transmission	9258 ft²	88998	-	9258 ft²	232191	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	10260 ft²	0	-	10260 ft²	4034	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	0 ft²	0	-	0 ft²	0	-
Overhead Lighting	196941 W	420040	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	188460 W	581842	-	0	0	-
People	663	108604	135935	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	30%	101117	0
>> Total Zone Loads	**-**	**1556592**	**135935**	**-**	**438174**	**0**
Zone Conditioning	-	1821942	135935	-	189845	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	100%	51855	-	0	0	-
Plenum Lighting Load	21%	141112	-	0	0	-
Return Fan Load	75983 CFM	0	-	15451 CFM	0	-
Ventilation Load	13262 CFM	220307	602252	13262 CFM	501860	0
Supply Fan Load	75983 CFM	149154	-	15451 CFM	-15463	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	1%	15566	-	1%	4382	-
>> Total System Loads	**-**	**2399936**	**738187**	**-**	**680623**	**0**
Central Cooling Coil	-	2399936	738401	-	0	0
Zone Heating Unit Coils	-	0	-	-	680543	-
>> Total Conditioning	**-**	**2399936**	**738401**	**-**	**680543**	**0**
Key:	**Positive values are clg loads Negative values are htg loads**			**Positive values are htg loads Negative values are clg loads**		

UNDERFLOOR SYSTEM: AIR SYSTEM SIZING SUMMARY

Air System Information

Air System Name	**Office area**		Number of zones	**3**	
Equipment Class	**CW AHU**		Floor Area	**104700.0**	ft²
Air System Type	**VAV**				

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	**Peak zone sensible load**		Calculation Months	**Jan to Dec**	
Space CFM	**Coincident space loads**		Sizing Data	**Calculated**	

Central Cooling Coil Sizing Data

Total coil load	**241.4**	Tons	Load occurs at	**Aug 1500**	
Total coil load	**2896.8**	MBH	OA DB / WB	**95.0 / 79.0**	°F
Sensible coil load	**2289.4**	MBH	Entering DB / WB	**87.1 / 69.7**	°F
Coil CFM at Aug 1500	**76723**	CFM	Leaving DB / WB	**59.5 / 57.9**	°F
Max block CFM at Oct 1500	**83164**	CFM	Coil ADP	**56.4**	°F
Sum of peak zone CFM	**83164**	CFM	Bypass Factor	**0.100**	
Sensible heat ratio	**0.790**		Resulting RH	**51**	%
ft²/Ton	**433.7**		Design supply temp.	**61.0**	°F
BTU/(hr-ft²)	**27.7**		Zone T-stat Check	**3 of 3**	OK
Water flow @ 12.0 °F rise	**483.09**	gpm	Max zone temperature deviation	**0.0**	°F

Supply Fan Sizing Data

Actual max CFM at Oct 1500	**83164**	CFM	Fan motor BHP	**59.65**	BHP
Standard CFM	**83017**	CFM	Fan motor kW	**44.48**	kW
Actual max CFM/ft²	**0.79**	CFM/ft²	Fan static	**3.10**	in wg

Outdoor Ventilation Air Data

Design airflow CFM	**13262**	CFM			
CFM/ft²	**0.13**	CFM/ft²	CFM/person **20.00**	CFM/person	

CONVENTIONAL OVERHEAD SYSTEM: AIR SYSTEM SIZING SUMMARY

Air System Information

Air System Name	Office area	Number of zones	3	
Equipment Class	CW AHU	Floor Area	104700.0	ft²
Air System Type	VAV			

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Peak zone sensible load	Calculation Months	Jan to Dec
Space CFM	Coincident space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	261.5	Tons	Load occurs at	Aug 1500	
Total coil load	3138.3	MBH	OA DB / WB	95.0 / 79.0	°F
Sensible coil load	2399.9	MBH	Entering DB / WB	82.3 / 65.9	°F
Coil CFM at Aug 1500	75983	CFM	Leaving DB / WB	53.0 / 51.6	°F
Max block CFM at Oct 1500	77255	CFM	Coil ADP	49.7	°F
Sum of peak zone CFM	74938	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.765		Resulting RH	40	%
ft²/Ton	400.3		Design supply temp.	55.0	°F
BTU/(hr-ft²)	30.0		Zone T-stat Check	3 of 3	OK
Water flow @ 12.0 °F rise	523.37	gpm	Max zone temperature deviation	0.0	°F

Supply Fan Sizing Data

Actual max CFM at Oct 1500	77255	CFM	Fan motor BHP	60.77	BHP
Standard CFM	77119	CFM	Fan motor kW	45.32	kW
Actual max CFM/ft²	0.74	CFM/ft²	Fan static	3.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	13262	CFM			
CFM/ft²	0.13	CFM/ft²	CFM/person	20.00	CFM/person

WEATHER SUMMARY

Site Name : Savannah, Georgia — Date : 10-28-03

TABLE 1. SITE DESIGN WEATHER DATA

Latitude	= 32 deg.	Elevation	= 52 Feet
Summer design dry bulb	= 96 F	Winter design dry bulb	= 24 F
Summer design wet bulb	= 77 F	Daily range	= 20 F

TABLE 2. PEAK SOLAR GAINS (Btu/(hr-sqft))

Month	N	NE	E	SE	S	SW	W	NW	H
January	7.6	17.5	129.6	184.7	184.2	184.7	129.6	17.5	156.9
July	18.1	149.6	188.4	120.6	43.4	120.6	188.4	149.6	279.6

Carrier peak solar data used.
Values corrected for altitude (52 ft), design dewpoint (69.7 F)
% Available Sunshine : Average data: Summer = 66 % ; Winter = 53 %

TABLE 3. OCCUPANCY SCHEDULE DATA

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Begin	OFF	8 A	8 A	8 A	8 A	8 A	OFF
End	OFF	6 P	6 P	6 P	6 P	6 P	OFF

Average occupancy : 10.0 hrs/day; 5.0 days/week
Number of summer shutdown days = 0

TABLE 4. TEMPERATURE BIN DATA

Bin Dry Bulb (F)	Bin Wet Bulb (F)	Bin Specific Humidity (lb/lb)	Bin Hours (hr/yr) Total Hours	Occupied Hours	Unoccupied Hours
96	77.0	0.0155	0.0	0.0	0.0
95	73.8	0.0129	28.9	17.9	11.0
90	71.1	0.0119	114.1	68.2	45.9
85	68.5	0.0110	361.5	204.3	157.2
80	65.8	0.0103	670.6	313.1	357.5
75	63.2	0.0096	884.8	311.4	573.4
70	60.6	0.0091	1006.3	295.9	710.4
65	57.9	0.0086	1029.8	286.6	743.2
60	55.3	0.0082	994.2	288.1	706.1
55	52.6	0.0079	961.0	285.1	675.9
50	50.0	0.0076	879.5	234.6	644.9
45	45.0	0.0063	718.4	149.8	568.6
40	40.0	0.0052	516.6	81.3	435.3
35	35.0	0.0043	318.7	40.9	277.8
30	30.0	0.0034	163.0	18.5	144.5
25	25.0	0.0027	70.9	7.5	63.4
24	24.0	0.0026	41.7	3.9	37.8
24	24.0	0.0026	0.0	0.0	0.0

FREE COOLING HOURS AVAILABLE PER YEAR

63°F — UNDERFLOOR SYSTEM FREE CLG AVAILABLE =1281 HRS APPROX.

55°F — OVERHEAD SYSTEM FREE CLG. AVAILABLE =821.6 HRS.