Applying DOAS and an Active Chilled Beam System for Optimizing Energy Efficiency at Clemson University AMRL

Photo by Fred Martin

Clemson University Advanced Material Research Laboratory
Anderson, SC

Architectural Engineering Senior Thesis Report

David Anderson
Mechanical Option

Thursday, April 12, 2007

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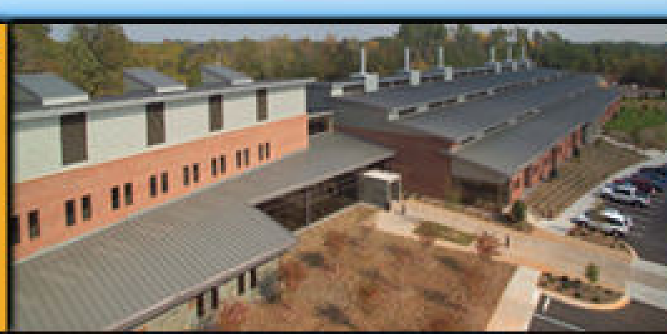
Anderson, SC



PROJECT INFORMATION

Project Cost: $18.5 Million
Size: 111,270 square feet
Project Delivery Method: Design-Bid-Build
Construction: Completed July 2004
Stories: Two
Function: Research Laboratory
Occupancy: Offices, Research Laboratories, Cleanroom, Conferencing

PROJECT TEAM

Owner: Clemson University
GC: Manhattan Construction Company
Architect: IDC Architects
Interior Designer: IDC Architects
Civil Engineer: IDC Architects
Structural Engineer: IDC Architects
MEP Engineer IDC Architects
Landscape: Arbor Engineering

ARCHITECTURE

Modern exterior including brick and metal galvalume panels with a Kynar finish

Interior walls are gypsum drywall finish

Uses clearstory daylighting for laboratories

LIGHTING/ELECTRICAL

480Y/277V, 3Φ, 4W service from (1) 2500 kVA transformer, (5) 30-112 kVA transformers to 208Y/120V, 3Φ, 4W service
(1) 300 kW stand-by generator
Various lighting including flourescent, drop-lighting, and wall washers

STRUCTURAL

Steel frame with steel truss

1st floor SOG with isolation for vibration

2nd floor concrete on metal deck

Braced frames for seismic vibrations

MECHANICAL

(2) 3,348 MBH gas fired boilers
(1) 4,094 MBH electric boiler
(3) 750 gpm, 266.6 ton chillers
(2) 1,125 gpm, 375 ton cooling towers
(15) AHU units ranging from 1,000-11,300 cfm
VAV boxes in lobby and office spaces
(4) MAH units ranging from 6,800-20,650 cfm

IDC ARCHITECTS

DAVID ANDERSON
MECHANICAL OPTION
HTTP://WWW.ARCHE.PSU.EDU/THESIS/EPORTFOLIO/2007/PORTFOLIOS/DJA173/INDEX.HTM
THE PENNSYLVANIA STATE UNIVERSITY
ARCHITECTURAL ENGINEERING

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Acknowledgements

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Secondly, a special thanks to the faculty and staff of AE. Through the last five years here, you have given me opportunities to learn from some of the best in the industry while showing your love for the work you do. You have presented challenges in order to shape a better engineer. Thank you for your support and dedication throughout the learning experience here at Penn State.

Finally, thank you to IDC Architects and Engineers along with Clemson University for allowing me to analyze their building. Without your knowledge and materials, my research would not have been possible. A special thanks to David Groseclose for taking time out of his busy schedule to answer questions and for supplying documents to my thesis.

Executive Summary

This report studies the proposed DOAS and Chilled Beams System for optimizing energy efficiency at Clemson University AMRL. It also evaluates the lighting compliance and re-analyzes the lighting systems. Along with computing calculations, there are initial cost break downs and yearly simulation data. This reports intent is not to differentiate IDC's design, but to illustrate other systems and their energy savings.

A number of programs, references, and documents were used in this report to compute and compile information. One of the programs used is Carrier's Hourly Analysis Program (HAP). This program was used to compute the yearly energy consumption of the AMRL. The building's existing Chilled Water VAV system's yearly energy consumption is $8,738,251. The proposed parallel system of DOAS with Active Chilled Beams had a yearly energy cost of $5,968,853. With a $2.7 million decrease in yearly costs, this constitutes a 31 % reduction in energy consumption. After running calculations, it is found that most of the building's sensible loads are met by incorporating 788 active chilled beams in the building, with DOAS taking care of all the latent loads and a small fraction of sensible loads. Not only does this decrease yearly cost and size of AHU's, but also drastically decreases environmental impact.

In accumulation to the depth analysis, breadth work was done in the lighting and construction options. In the lighting breadth, over half of the spaces had an excess in wattage according to ASHRAE Standard 90.1-2004. These areas of the building were re-designed to decrease wattage/sq. ft. while maintaining adequate lighting. This allows a decrease in yearly energy consumption and it also lowers environmental impact. In the construction management area, I analyzed the initial costs of the current Chilled Water VAV System and compared it to the proposed DOAS with Active Chilled Beams. It is approximated that a VAV system costs $12/scfm, whereas a DOAS with Chilled Radiant Colling Panels (CRCP) costs a mere $8/sq.ft. The new proposed system will be more cost effective, costing $1.17/sq.ft less than the current system. Other items analyzed are the impacts of schedule due to different systems and an increase in pumps and plumbing equipment.

Project Background

Lobby at Clemson AMRL

Project Name: Clemson University Advanced Materials Research Laboratory

Location: Anderson, SC

Occupant: Clemson University

Size: 111,270 sq. ft.

Number of Stories: 2 Above Grade

Primary Project Team:

Owner: Clemson University

Architecture Firm: IDC Architects

Persons To Be Credited: John Henderson, Nathan Corser, Barbara Springer, Magda Gerencer, David Groseclose, Joe Simpkins, Tony Neal, Katrina Cobb

Contractor: Manhattan Construction Company

Landscape Architect: Arbor Engineering

Interior Designer: IDC Architects

Laboratory at Clemson AMRL

Completion Date: July 2004

Cost Information: $18.5 million

Project Delivery Method: Design-Bid-Build

*photos by Fred Martin

Clemson University's Advanced Materials Research Laboratory in Anderson, SC is the first LEED Silver certified facility in South Carolina and the only certified nanotechnology research lab in the United States. A checklist from the U.S. Green Building Council's LEED for New Construction was used to evaluate the building in all aspects. Clemson University ARML proposed 38 out of 62 credits. The certification goal for this project is Silver. The project proposed credits in the following categories: Sustainable Sites – 9, Water Efficiency – 4, Energy and Atmosphere – 4, Materials and Resources – 4, Indoor Environmental Quality – 12, and Innovation and Design – 5. Clemson University's AMRL was given Silver Certification after review, receiving 33 out of 69 points.

Building Systems Overview

Building Envelope:

The building has a structural steel frame, with interior finish steel studs and a gypsum dry wall finish. Its exterior materials are brick and metal panels. A typical section is shown in figure 1. The metal panels are Galvalume metal panels with a Kynar finish. Standing seam metal roofing is Galvalume with Kynar finish. Windows are a mixture of aluminum storefront and curtain wall. There is a single ply membrane roof over the mechanical equipment. ASHRAE Standard 90.1 is a tool which evaluates the building envelope and lighting systems used in the building, not the mechanical energy performance. This standard requires no more than 50% of the building envelope to be glass. Clemson ARML meets this requirement with only 15.9% fenestration.

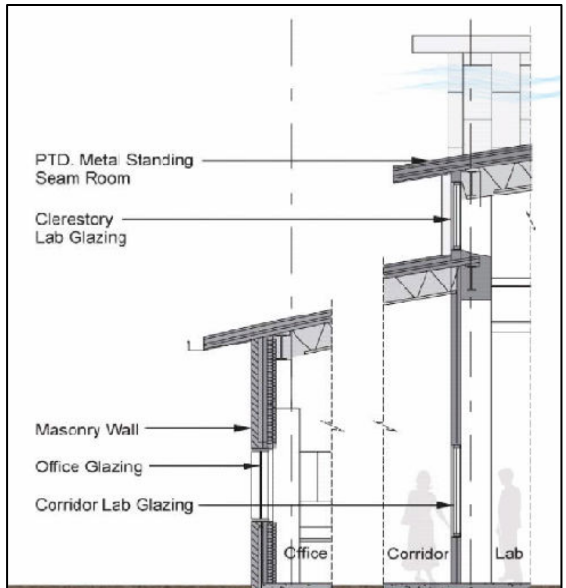


Figure 1: Typical Section

Electrical:

The building is served by 408Y/277V, three phase, 4 wire service from one 2500kVA Transformer. The system also includes five 30-112 kVA transformers which step the service down to 208Y/120V, three phase, 4 wire service. There is also one 300 kW diesel fired stand-by generator for emergency energy.

Mechanical:

The cold water system feeds fifteen air handling units, three of them having VAV's, and 4 MAH units serve Clemson AMRL. The units conditioned air to offices, laboratories, conference areas, and clean rooms. The MAH's were needed to supplement the vast amount of exhaust air from the fume hoods. VAV's were prominent in the office areas, due to conformability issues. The mechanical system also includes cooling towers, chillers, and boilers, all to be discussed in the "Existing Mechanical Systems" section to follow.

Structural:

The building was designed for 50 psf in office areas and 30 psf in mechanical spaces. The snow load was designed for 14 psf. Wind loads were used in design with a wind speed of V3a (90 mph). The ground level is comprised of 5" concreted slab with 4x4 welded wire fabric (WWF) on 2" base of sand with 6 mil poly vapor barrier over 6 " aggregate base on compressed soil. The elevated floors are comprised of a 2-1/2" slab on a 1-1/2" deck. The concrete is 4000 psi with a normal weight of 150 pcf. Floor slabs were placed with WWF in flat sheets, not rolls. In re-entrant corners for pits and recesses, (2) #4 bars were used for reinforcing. In sector A as seen in Figure 2, many beams and girders were used in constructing this building. Sector A had W21x44, W12x22, W12x16, W21x44, W18x35, and W16x31 beams bolted to W24x62,

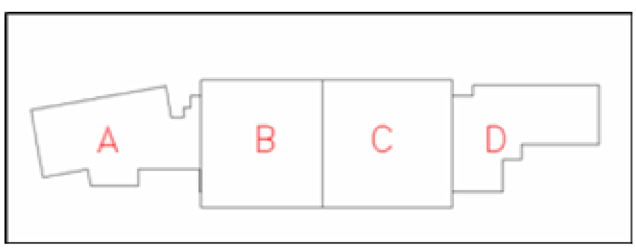


Figure 2: Building Sections

W24x55, and W24x68 girders. Sector B had W8x13, W14x26, W16x31, and W24x55 beams bolted to W36x210, W36x245, W36x280 and W36x300 girders. Finally, sector C includes W12x14, W14x22, W14x30, and W18x35 beams bolted to W18x50, W36x280, and W36x300 girders. Finally sector D is comprised of W12x16 and W 12x19 beams bolted to W8x13 and W12x19 girders. The columns of the building were comprised of W18, W16, and W14 attached with moment connections for seismic and wind loads.

Fire Protection:

The building is equipped with 1 hour shaft enclosures and fire partitions. The entire building is outfitted with sprinklers and a fire alarm system. A Honeywell FS-90 DGP is used to match the existing university system. The building is not resisted to fire through walls nor floor construction. The shaft enclosures and fire partitions are presented by UL with design numbers U465 and U906 respectively.

Transportation:

From Figure 2 previously shown, Sector A contains one elevator two stairwells. One stairwell is open to the lobby as it ascends to the second floor. The second stairwell is located in the west end show in Figure 3 below servicing the office spaces. There is one other stairwell which is located in Sector D in Figure 2 and also shown below in Figure 3. This services transportation to the upper level penthouse region.

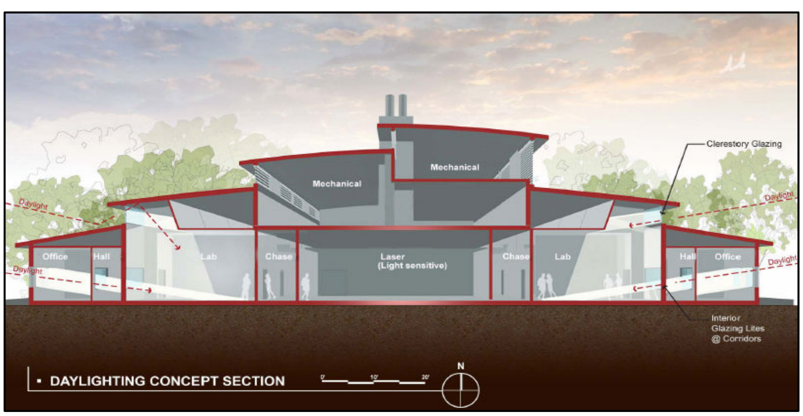
Also shown below in Figure 3 is how the spaces are designated on the first floor of Clemson AMRL. The orange spaces represent laboratories; the yellow areas represent laboratory support. The off white spaces are shared spaces and circulation. The blue areas are offices spaces and the gray areas belong to the support/services.

Figure 3: Building Operations

Existing Mechanical Systems

AHU

Clemson University AMRL is a two-story mixed use building located in Anderson, SC. This 111, 270 sq ft. building houses office space, laboratories, conference rooms, and clean rooms. There are 15 AHU's and 4 MAH's that condition this building. The mechanical system uses an on site heating and cooling plant to condition air for the AHU's and VAV distribution system. AHU numbers 8, 10, and 11 serve VAV boxes which supply air to the spaces. A vast majority of the mechanical equipment is located on the second floor penthouse, where there is a small space allocated on the east wing for additional equipment. Clemson University ARML, due to its many laboratories, requires a lot of mechanical equipment. In design, they used mostly an entire floor to house the mechanical equipment. With this, the total area of the mechanical space on the second floor is 31,841 sq. ft. After calculating the areas other than the mechanical floor space, such as the draw tower and first floor mechanical



Section of AMRL

room, there is a total of 35, 626 sq. ft. of lost rentable space. Out of 117,000 sq. ft, 30.4 % of this area is given to the mechanical equipment.

The AMRL is served by 19 units, ranging from 1,000 cfm to 20,650 cfm. The amount of minimum outside air to the AHU's varying between 300 to 20,650 cfm. As noted before, the rooms serviced by AHU 8, 10, and 11 serve VAV boxes to control the climate which people occupy.

Clemson AMRL uses two 3,348 MBH gas fired boilers and one 4,094 MBH electric boiler. There are three 750 gpm/266.6 ton chillers and two 1,125 gpm/375 ton cooling towers. The air supplied to the building is from the fifteen AHU's ranging from 1,000-11,300 cfm and four MAH units ranging from 6,800 to 20,650 cfm.

Mechanical System

-Air Handling Units/ Make-Up Air Handling Units

Fifteen total air handling units, three of them serving VAV boxes, and 4 MAH units serve Clemson AMRL. They provide conditioned air to offices, laboratories, conference areas, and clean rooms. MAH units were needed to condition the additional space since an abundance of air was exhausted through the fume hoods. Appendix A shows the design SA and OA along with the calculated V_{ot} from Technical Report 1.

AHU-1

Air-Handling Unit 1 services 2,568 sq. ft. which houses conference/meeting, corridor, and office spaces. The design primary supply flow rate was 4,000 cfm.

AHU-2

Air-Handling Unit 2 services 2,968 sq. ft. which houses break rooms, corridors, restrooms, and office spaces. The design primary supply flow rate was 4,500 cfm.

AHU-3

Air-Handling Unit 3 services 3,228 sq. ft. which houses communication rooms, corridors, restrooms, conference, and office spaces. The design primary supply flow rate was 5,700 cfm.

AHU-4

Air-Handling Unit 4 services 2,876 sq. ft. which houses conference/meeting areas, corridors, and office spaces. The design primary supply flow rate was 5,200 cfm.

AHU-5

Air-Handling Unit 5 services 4,128 sq. ft. which houses laser labs and instrument rooms. The design primary supply flow rate was 6,300 cfm.

AHU-6

Air-Handling Unit 5 services 4,128 sq. ft. which houses laser labs and instrument rooms. The design primary supply flow rate was 5,800 cfm.

AHU-7

Air-Handling Unit 7 services 5,080 sq. ft. which houses office spaces and corridors. The design primary supply flow rate was 5,000 cfm.

AHU-8

Air-Handling Unit 8 services 5,314 sq. ft. which electrical and data, break, seminar rooms, along with corridors and the lobby space. The design primary supply flow rate was 10,600 cfm.

AHU-9

Air-Handling Unit 9 services 5,312 sq. ft. which houses prep labs, electrical analysis rooms, along with other assorted laboratories. The design primary supply flow rate was 11,300 cfm.

AHU-10

Air-Handling Unit 10 services 5,005 sq. ft. which houses conference and office spaces, along with a break and copy/mail/storage room. The design primary supply flow rate was 7,000 cfm.

AHU-11

Air-Handling Unit 11 services 5,630 sq. ft. which houses office spaces and corridors. The design primary supply flow rate was 7,100.

AHU-12

Air-Handling Unit 12 services 1,828 sq. ft. which houses office spaces, a HAZ MAT room, corridors and equipment rooms. The design primary supply flow rate was 3,100 cfm.

AHU-13

Air-Handling Unit 13 services 1,752 sq. ft. which houses a clean room, a gowning vestibule, and device lab. The design primary supply flow rate was 1,600 cfm.

AHU-14

Air-Handling Unit 14 services 528 sq. ft. which houses the STM lab and its respectful prep room. The design primary supply flow rate was 1,000.

AHU-15

Air-Handling Unit 15 services 1,232 sq. ft. which houses the maintance room and office space along with the draw tower. The design primary supply flow rate was 6,.800 cfm.

MAH-1—4

See Appendix B for the supply air values for these units supplying the laboratory spaces.

-Cooling Towers

Two 375 ton, 1,125 gpm cooling towers are located on site. The cooling towers provide condenser water for the 15 AHU's.

-Chillers

Three 266.6 ton, 750 gpm chillers are located at the AMRL.

-Boilers

Two 3,348 MBH gas fired boilers and one 4,094 MBH electric boiler are located at Clemson's AMRL.

Boilers

-Energy Recovery Coil

Clemson's AMRL uses three energy recovery coils on the air side portion of the system. They are located in fume hood exhaust ducts to recuperate energy They provide cooling for the condenser water loop from the cooling towers and heat for the hot water loop from the boilers.

-Variable Air Volume Boxes

The conditioned air from AHU 8, 10, and 11 is ducted to several variable air volume (VAV) boxes, which are located in the ceiling plenum. The boxes are selected for specific ranges of cfm. There are also different gpm rates for the hot water reheat coils to each of the VAV boxes.

-Basic System Operation

Clemson's AMRL contains of both air-side and water-side mechanical equipment and systems. The air-side consists of AHU's, MAH's, and VAV boxes. An example of the air-side schematic is shown in Appendix C. The water-side operation consists of a hot water system and a condenser water system. The hot water system is shown in Appendix D and the condenser water system is shown in Appendix E.

-Outdoor and Indoor Design Conditions

-Outdoor Design Conditions:

The 2004 ASHRAE Fundamentals handbook provides weather data in Chapter 27. Table 1 below shows the location data. Table 2 illustrates the design outdoor conditions

Latitude	34.50
Longitude	82.72
Elevation	771 feet

Table 1:Locatoin

Summer Conditions		Design Dry Bulb:	93 °F
Winter Conditions		Design Dry Bulb:	19 °F

Table 2:Desidgn DB

-Indoor Design Conditions

Table 3 below illustrates the indoor design conditions.

Dry Bulb Temperature:	74 °F
RH:	50%

Table 3:Indoor Air Requirements

Design Considerations

-*Co-Generation*

Co-generation is one alternative to the design of Clemson AMRL building. A building using co-generation makes electricity of site, and thus less energy loss due to transmission. The heat from the burning fuel, can be utilized and help heat the building.

-*Ground Source Heat Pumps*

Ground source heat pumps were also taken into consideration. With the climate allowing for such a design, this would also be a great benefit to the owner. Since the building takes setting in a non urban environment, this also makes this design appealing. Similar to a GSHP, one could use water source heat pumps and store water in a large tank underground to help with the load of the building.

-*Thermal Storage*

Thermal storage was another alternative to the design to help decrease energy costs. One could produce ice in the evening, when utilities are cheaper, and store it for the following day for cooling. Energy recovery wheels are also an option in design. The only downfall is that desiccant wheels can only be used to the laboratory spaces. Enthalpy wheels are able to recover energy and moisture since they mix the exhaust and supply air streams. A desiccant wheel does not transfer contaminants. Instead, the wheel is flushed with supply air in the purging section of the rotor.

Mechanical System Design

Rising costs in fossil fuels and energy must make owners and designers aware of more efficient and greener systems. In order to obtain the energy reduction in the existing building, chilled beams incorporated with DOAS will be one of the options used in this study.

-Introduction

There are two different chilled beams, passive and active. One can incorporate a chilled ceiling with overhead or under floor ventilation, and or chilled slab with under floor ventilation. With overhead ventilation, there is a limited capacity to absorb heat gains. Under floor ventilation has improved capacity to absorb heat gains and excellent in comfort conditions. A chilled slab with under floor ventilation has a cooling capacity up to 70 W/sq. m (6.5 W/sq.ft.). Exposed lighting is required with this type of set up.

- *Passive versus Active*

Passive chilled beams have a chilled surface formed into a linear finned coil, which is surrounded by a pressed steal casing. These are able to be suspended from the ceiling, with flush mounts also available. Warm air rises to the ceiling and enters the top of the beam, where it is cooled by contact with the cold coil. The cool air then descends into the room through slots underneath the beam.

Active chilled beams incorporate tempered ventilation air supplied through ducting in the beam itself. The tempered air leaves the supply ducting through slots with a higher velocity that induces warm air into the beam and through the cooling coil, reducing its temperature. A simple schematic is shown in Figure 4. The supply and chilled room air mix and enter the room out of the slots under the beam. With active chilled beams, room temperature is achieved by controlling of individual or groups of beams. They have a cooling capacity up to 100 W/sq m (9.29 W/sq.ft.) and also have integrated lighting as option and can be fully recessed.

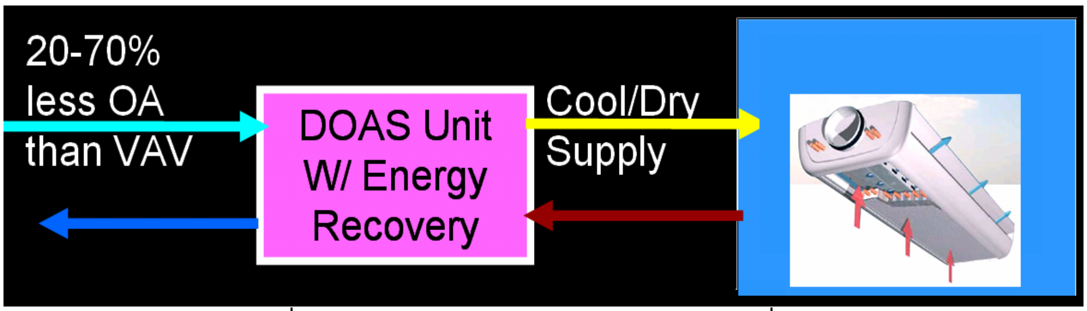


Figure 4: System Schematic

The advantages of chilled beams include low maintenance since there are no internal fans or filters. Low fan speed is used to deliver air to the outlet diffusers which in return, have a low energy requirement. The chilled beams also operate at relatively high chilled water flow temperatures, meaning the chillers have to do less work than for a fan coil system. Expect a CWT of 55-65˚F in chilled beams, compared to 40-45˚F They can be incorporated into the fire suppression system to eliminate extra plumbing, and some chilled beams contain everything from lighting, data lines, and fire suppression systems.

Energy recovery wheels will also be incorporated into the re-design. The only downfall is that desiccant wheels need to be purged in order to utilize laboratory exhaust. Enthalpy wheels are able to recover energy and moisture transferring it between exhaust and supply air streams. A purged desiccant wheel does not transfer contaminants. Instead, the wheel is flushed with supply air in the purging section of the rotor as shown in Figure 5.

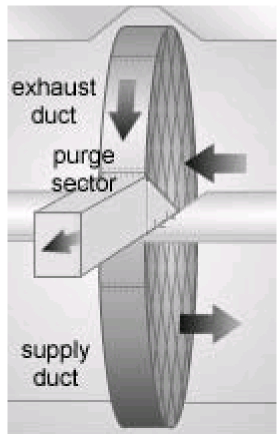


Figure 5: Desiccant Configuration

Using active chilled beams in the redesign process, there isn't any significant issues present. Space is available for extra equipment, but coordination with plumbing will be a must for the spaces due to the units. There will be a decrease in AHU sizing along with the associated ductwork.

Chilled Beam Analysis

Background:

Dedicated Outdoor Air Systems, DOAS, are becoming widely known and used in the industry. DOAS systems are usually integrated with a parallel system. The parallel system used in the analysis is Active Chilled Beams. Using a DOAS system not only reduces the duct, shaft, and equipment sizes, but also drastically reduces fan energy, increases humidity control, and decreases initial costs. The entire latent loads are met by the DOAS along with some of the sensible loads. The remaining sensible heat is to be conditioned by the active chilled beams. An enthalpy wheel along with a desiccant wheel will be used in the design to maximize heat recovery.

DOAS supplies cool dry OA to the system. This ensures that active chilled beams can be applied without condensation concerns. As long as the panel temperature remains above the space dew-point temperature, condensation will not occur. . Figure 6 below shows the air flow of the active beam, along with the high induction diffusers. With a lower room dew-point temperature, the lower the supply water temperature can be. Similarly, a lower mean plate temperature would allow a higher rate of heat removal. Radiant loads are treated directly and the supply air does

Figure 6: Active Chilled Beam

not exceed that required. Remember that the lower the SAT, the less sensible cooling will be needed by the beams. Another advantage is that it could be incorporated into the automatic sprinkler piping system.

Calculations:

As shown in Figure 7 below, the set-up of the Dual Wheel DOAS system is illustrated. Below are calculations based on points across the system.

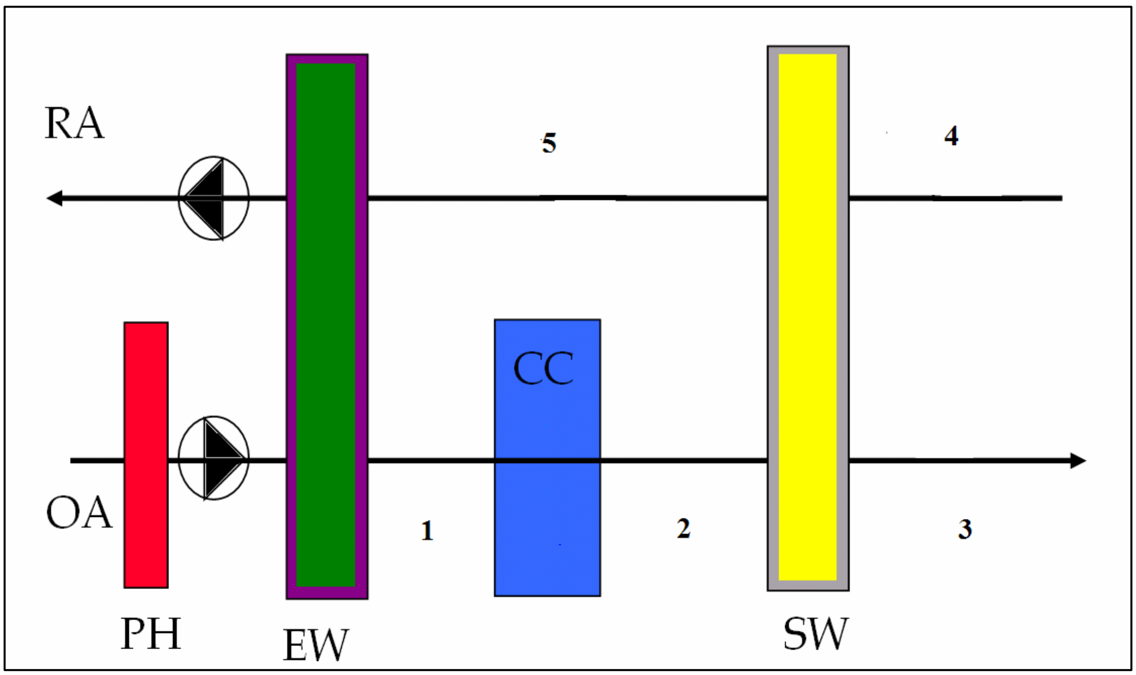


Figure 7: Dual Wheel DOAS

Example using AHU-1, All numbers are included in Appendix F

Latent Load:

Occupancy = 20 people for AHU-1

Q_{latent} = 200 Btu/h*person (0.0586 kW/person)

Q_{latent} = 200Btu/h*person x 20 people = 4000 Btu/h (1.172 kW)

Outdoor Air Conditions:

Dry Bulb = 93 ˚F

Humidity Ratio = 118 gr/lbma (0.01689 kg/kg)

Desiccant Wheel:

Make: Xetex

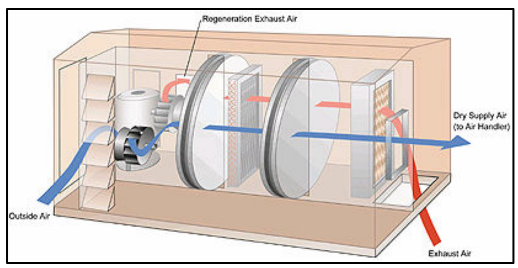
Model: AIRotor 2500

Sensible Effectiveness: ε_S=0.76

Latent Effectiveness ε_S= 0.65

Volumetric Flow Rate 10,280

Face Velocity: 525 sfpm



DOAS AHU With Dual Wheels

-*Points of Interest (Figure 7)*

Space Air Conditions (Point 4):

Dry Bulb Temperature = 79 ˚F

Humidity Ratio = 66 gr/lbma (0.0094 kg/kg)

Supply Air Temperature: 74 ˚F

Design Conditions (Point 1):

$W_{OA\text{-}EW} = -\varepsilon_S \text{ x } (W_{OA} - W_{RA\text{-}SW}) + W_{OA}$

$= - (0.76) \text{ x } (0.01689 \text{ kg/kg} - 0.0094 \text{ kg/kg}) + 0.01689 \text{ kg/kg}$

$= 0.011198 \text{ kg/kg } (78.39 \text{ gr/lbma})$

$DBT_{OA\text{-}EW} = -\varepsilon_L \text{ x } (DBT_{OA} - DBT_{EW\text{-}SW}) + DBT_{OA}$

$= - (0.65) \text{ x } (93^\circ F - 74^\circ F) + 93^\circ F$

$= 80.65^\circ F$

Design Conditions (Point 3):

$Q_{latent} = 0.68 \text{ x cfm x } \Delta W$

$$W_{SA} = W_{RA} - \left(\frac{Q_{latent}}{0.68 \times cfm}\right)$$

$$= 66 \text{ gr/lbma} - \left(\frac{102{,}800 Btu/h}{0.68 \times 10{,}280 cfm}\right)$$

$= 51.29 \text{ gr/lbma } (0.00733 \text{ kg/kg})$

$DBT_3 = 72^\circ F$

Design Conditions (Point 2):

$$W_B = \frac{-Q_{latent}}{0.68 \times cfm} + W_{Space}$$

$$= \frac{-102{,}800 Btu/h}{0.68 \times 10{,}280 cfm} + 66 \text{ gr/lbma}$$

$= 51.29 \text{ gr/lbma } (0.00733 \text{ kg/kg})$

$DBT_2 = 67\ ^\circ F$

Selecting Quantity of Chilled Beams

Taken from the article "Ceiling Radiant Cooling Panels as a Viable Distributed Parallel Sensible Cooling Technology Integrated with Dedicated Outdoor Air Systems" by Dr. Stanely A. Mumma and Christopher L. Conroy, is the process used to determine the amount of CRCPs per square foot.

Define Room Design Conditions

Dry Bulb Temperature: 74 ˚F

Relative Humidity: 40-60%

Room Dew Point Temperature: 54˚F

Minimum Rate of Heat Removal Needed

The table in Appendix G is taken from the article mentioned above. The amount of heat removal is based on the room's dry bulb temperature and RH. The following shows RH and heat removal respectively:

40% RH → 95 W/m^2

60% RH → 32 W/m^2

Sensible Cooling Served by Chilled Beams

Building Area: 111, 270 sq ft.

Occupancy: 514 people

Combined Sensible Load: 3 W/sq. ft.

Building's Total Sensible Load:

Q_{total}= 3 W/ sq. ft. x 111,270 sq. ft.

= 333,810 W (1,139,294 Btu/h)

Outdoor Air Supply: 20 scfm/person

Ventilation Air:

M-dot = 20 scfm/person x 514 people

= 10,280 scfm

Sensible Load Achieved by DOAS

Q_{DOAS}= M-dot x Cp x ΔT

Q_{DOAS}=10,280 x 0.244 x (93-54) ˚F

Q_{DOAS}= 97,824 Btu/h

Sensible Load Achieved by Chilled Beams

Q_{Beams}= Q_{Total} - Q_{DOAS}

Q_{Beams}= 1,139,293 Btu/h- 97,824 Btu/h

Q_{Beams}= 1,041,469 Btu/h

Selected Chilled Beam

TROX—DID300 @ 76 W/m^2 with L_n of 3000mm

Beam Coverage: $$\frac{Q_{DOAS}}{Q_{BEAM}} = \frac{1{,}041{,}469\,btu/h}{24.10\,\frac{btu}{hft^2}}$$

= 43,214.48 sq ft

Total number of Chilled Beams:

$$\frac{BeamAreaCoverage}{AreaOfBeam} = \left(\frac{43{,}214.48}{54.896}\right) \text{ sq. ft.}$$

=788 Active Chilled Beams

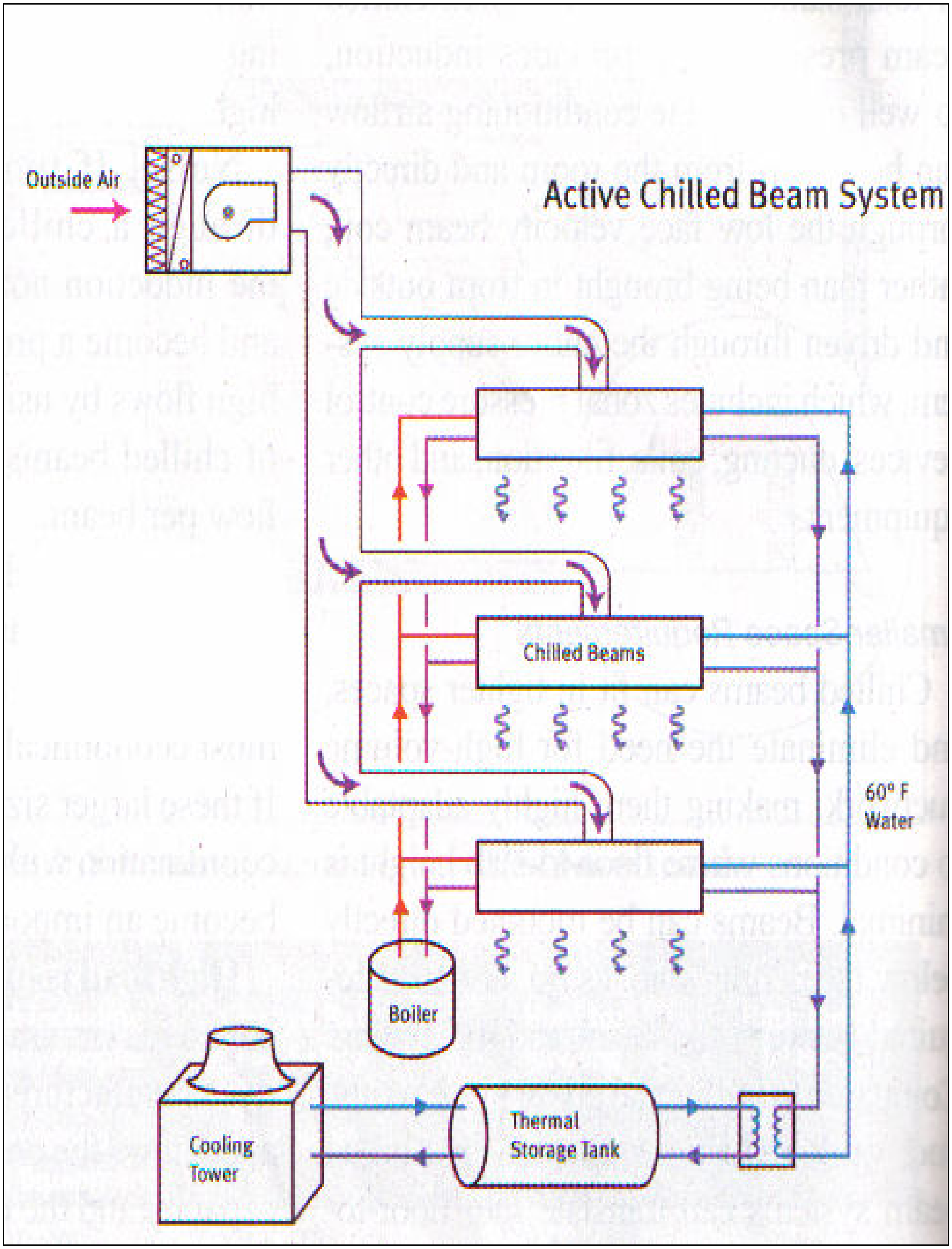
Re-Sizing of AHU's

Due to using chilled beams with DOAS, the beams were able to take care of the sensible load in the building, therefore reducing OA with the DOAS. Table 4 below shows the difference in size from the original scheme to the new DOAS scheme.

AHU #	Original SA(cfm)	Design OA(cfm)	Vot (cfm)	DOAS Resized OA (cfm)
1	4000	1800	324	594
2	4500	1800	257	594
3	5700	1800	462	594
4	5200	1800	317	594
5	6300	6300	1784	2079
6	5800	5550	1784	1832
7	5000	400	399	132
8	10600	1050	737	347
9	11300	3350	1167	1106
10	7000	800	561	264
11	7100	550	600	182
12	3100	2550	276	842
13	1600	1100	365	363
14	1000	300	275	99
15	6800	2000	253	660
Totals	85000	31150	9561	10280

Table 4: AHU Information

Schematics of Proposed DOAS with Chilled Beams



Lighting Analysis

Background:

The lighting in Clemson AMRL is comprised of 24"x 48" florescent fixtures with parabolic and lens troffers. Fixtures include T8, T5 lamps using rapid start ballasts, and down lights incorporating quad compact fluorescents inside the building. Metal Halides provide lighting on the exterior. The use of low voltage lighting is not permitted at Clemson University, due to the university's specification 16501, "Interior Lighting".

Lighting Compliance

Maximum lighting power densities are suggested by Standard 90.1. Not only does lighting consume energy, but it also creates heat in the space, which in return increases cooling loads. Table 9.5.1 makes suggestions on the maximum lighting density according to each space. Appendix H shows this table.

According to the lighting calculations given by IDC, the calculated W/ft^2 are as follows:

Area	W/sq. ft.
Office	1.10
Office	1.32
Office	1.50
Office	1.68
Prep Lab	1.44
Lab	1.68
Lab open	1.85
Corridors	0.82
Corridors	0.83

Area	W/sq. ft.
High Bay	0.65
Haz Mat	1.08
Waste Storage	1.95
Mech	0.39
Mech	0.40
Mech	0.43
Mech	0.49
Mech	0.55

Table 5: W/sq ft Calculations

By the space by space calculations and in accordance to Appendix D, all spaces exceed except the corridors, an office area, the high bay area, Haz Mat, and the mechanical rooms.

It may be possible to achieve the same amount of output, with less energy, by selecting high efficient T5 lamps to replace the standard T8 lamps. There is a possibility that the spaces could be supplied with fewer lamps and still achieve the same lighting requirements. T5 lamps tend to be more expensive than the T8 lamps, but life expectancy is far greater and thus gives a better life cycle cost. Replacing the existing 40 Watt T8 with a 32 watt T5 lamp shows a reduction in power density, thus decrease in energy. Table 6 below shows the results after analysis.

Space	Area	W/Lamp	W/Lamp proposed	# Lamps
Office	3200	40	32	106
office	2600	40	32	98
Office	3400	40	32	143
Prep Lab	4100	40	32	148
Lab	3500	40	32	147
Lab Open	4200	40	32	194
Waste	600	40	32	29

Watts	Watts proposed	Power Density	Power Density proposed
4224	3379	1.32	1.06
3900	3120	1.5	1.20
5712	4570	1.68	1.34
5904	4723	1.44	1.15
5880	4704	1.68	1.34
7770	6216	1.85	1.48
1170	936	1.95	1.56

Table 6: Proposed Lighting Densities

The total reduction in the lighting densities was significant. The original lighting scheme reached 41, 155 watts for the building. With the proposed re-design and decreasing the areas in need, the watts achieved were 34, 243 watts. This results in a 20% reduction in energy usage alone.

Construction Impact Analysis

The installed cost of a CRCP system is approximately $8/sq.ft. For the VAV system to handle the same loads, the AHU's alone cost about $2/scfm, the ductwork an additional $4/scfm and the VAV boxes at $6/scfm. The total amount for the VAV system is approximately $12/scfm. Which after running calculations and interpolating them with Table 7, we are to find that there will be $129,840 decrease in initial cost. Also shown in Appendix I is a sample of the reduction of costs comparing VAV with a DOAS in a 186,000 sq. ft. building in Philadelphia, PA.

SHV 1003 HVAC		**3,024,000**
SHV 1010 heat/cooling equipment	700,000	
SHV 1020 AHU/MAU	300,000	
SHV 1030 reheat coils	110,000	
SHV 1040 dehumidification	100,000	
SHV 1050 exhaust fans	70,000	
SHV 1060 ductwork	400,000	
SHV 1070 piping and supports	520,000	
SHV 1080 pumps	24,000	
SHV 1090 Phoenix Control System	400,000	
SHV 1100 insulation	350,000	
SHV 1200 LEED Commissioning	50,000	

Table 7: Installation/First Costs

The initial cost was $3,024,000 shown above in Table 7. The price for the chilled beam units is approximated to be $2,764,000. This is 81% of the cost of a standard VAV system. Keep in mind that replacing fan with pump energy, the initial $5,658,000 system will begin to look appealing.

Schedule impact was minimal since the same amount of time is required during the erection of a CWP CAV/VAV system as with a DOAS with Chilled Beams. With DOAS, AHU's will be smaller and ductwork will be significantly less. The only possible impact would be the extra pump installation or contractor unfamiliarity with the proposed system. Since this type of system is more abundant in Europe and Australia, and not here in the United States, finding contractors that are familiar and comfortable with this design may be short. Contractors may also apply a premium cost with such a design. Coordination would be very similar on the CW and Air sides, with similar equipment.

Overall Cost Analysis

The design cooling and heating loads for the major equipment are calculated using Carrier's Hourly Analysis Program. HAP is used to estimate the annual consumption of energy for the AMRL as well.

Carrier's HAP was used to simulate and model the Clemson AMRL's energy consumption. In order to compute this, weather conditions were properly selected for the buildings site. HAP inputs the correct weather data for the design and simulation city, which was from 2001 ASHRAE Fundamentals Handbook.

Energy Sources and Rates

The Clemson AMRL is serviced by both electricity and natural gas energy. The electric service is provided by Duke Power. The rates can be seen in Figure 8. The natural gas service is provided by Piedmont Natural Gas. The rates can be seen in Figure 9.

RATE:

I.	Basic Facilities Charge	$33.54	
II.	Demand Charge	Summer Months June 1 – September 30	Winter Months October 1 – May 31
	A. On-Peak Demand Charge per month		
	For the first 2000 KW of Billing Demand per month	$13.16 per KW	$7.69 per KW
	For the next 3000 KW of Billing Demand per month	$11.67 per KW	$6.40 per KW
	For all over 5000 KW of Billing Demand per month	$ 9.40 per KW	$4.74 per KW
	B. Economy Demand Charge per month	$1.01 per KW	$1.01 per KW
III.	Energy Charge		
	A. All On-Peak Energy per month	4.3937 cents per kWh	4.3937 cents per kWh
	B. All Off-Peak Energy per month	1.7336 cents per kWh	1.7336 cents per kWh

DETERMINATION OF ON-PEAK AND OFF-PEAK HOURS

	Summer Months June 1 – September 30	Winter Months October 1 – May 31
On-Peak Period Hours	1:00 p.m. – 9:00 p.m. Monday – Friday	6:00 a.m. – 1:00 p.m. Monday – Friday
Off-Peak Period Hours	All other weekday hours and all Saturday and Sunday hours.	

Figure 8—Duke Power Costs

Rate Classification	Facility Charge	Units	Rate/Therm November/March	Units	Rate/Therm April/October
	250.00	First 15,000	1.19349	First 15,000	1.12654
Demand (Therm)	1.90	Next 15,000	1.13290	Next 15,000	1.08143
		Next 75,000	1.08558	Next 75,000	1.05278
		Next 165,000	1.04020	Next 165,000	1.02163
		Next 330,000	0.99909	Next 330,000	0.99409
		Over 600,000	0.97052	Over 600,000	0.97052

Figure 9—Piedmont Natural Gas Costs

The following are charts computed from Carriers HAP. These charts are related to the original VAV system. Table 8 shows the annual costs of the VAV system, whereas table 9 shows the annual costs of a DOAS with Chilled Beams application.

Component	Sample Building ($)
Air System Fans	1,379,405
Cooling	925,442
Heating	7,019
Pumps	88,394
Cooling Tower Fans	932,159
HVAC Sub-Total	**3,332,418**
Lights	2,389,184
Electric Equipment	3,016,649
Non-HVAC Sub-Total	**5,405,833**
Grand Total	**8,738,251**

Table 8. Annual Costs VAV

Component	Sample Building ($)
Air System Fans	69,342
Cooling	229,434
Heating	3,354
Pumps	169,355
Cooling Tower Fans	115,958
HVAC Sub-Total	**587,444**
Lights	2,378,390
Electric Equipment	3,003,020
Non-HVAC Sub-Total	**5,381,410**
Grand Total	**5,968,853**

Table 9. Annual Costs DOAS w/ Chilled Beams

As shown in the above Tables, there is a $2,769,398 savings per year in operational costs. Which translates to a 31% cost reduction yearly.

The following pie charts represent the comparison of annual component costs for VAV systems versus DOAS with Chilled Beams. Figure 10 represents the VAV system, whereas Figure 11 represents the parallel DOAS.

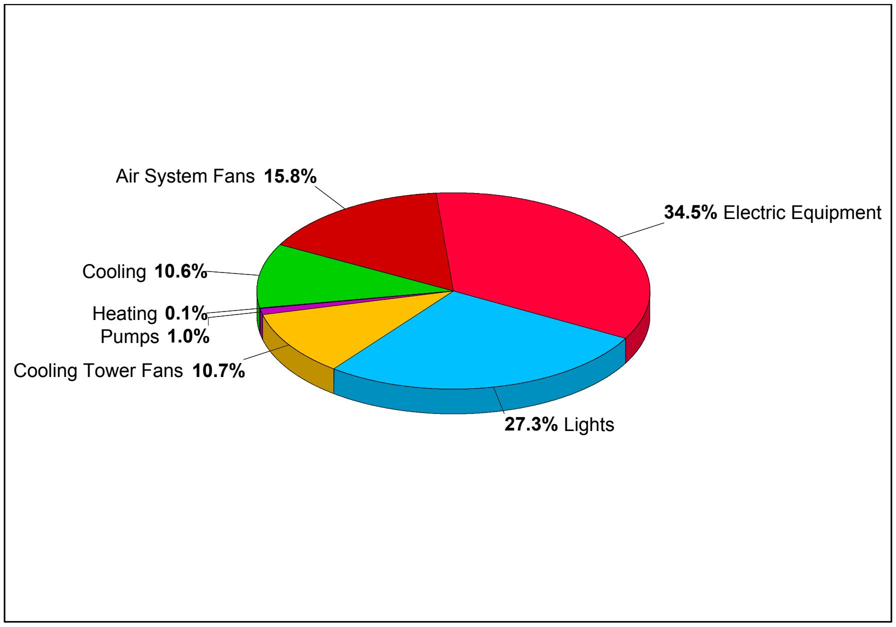


Figure 10: VAV Component Cost

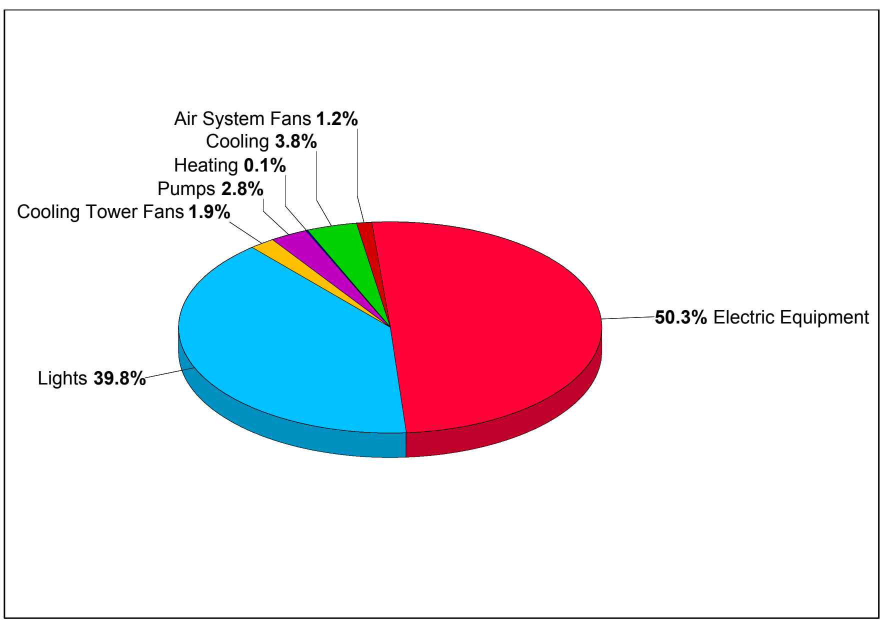


Figure 11: DOAS w/ Chilled Beams Component Cost

-*Life Cycle Analysis*

As stated previously, the initial cost of the existing system was $3,024,000. Carrier's HAP simulated the yearly energy consumption to be $8,738,251. The new proposed DOAS with Chilled Beams had an initial cost of $2,764,000 for the beams and $2,894,160 for the remaining equipment, which totals $5,658,160 for an initial. The simulated yearly consumption of energy for the proposed system is $5,968,853. The DOAS with Chilled Beams was $2,634,160 more than the initial cost of the existing system, but saves $2,769,398 per year. With this proposed system, the payback would be less than one year for this building.

Conclusions

The increasing fuel cost is important to any building owner, which reflects on how much money they have to spend. Initial costs are usually the selling point in which system is to be chosen, but it is wise to compute yearly costs and paybacks to see which system is more efficient on cost basis. As seen above, the initial cost of the DOAS with Chilled Beams is 47% more than that of the existing CAV/VAV system. By simulating building conditions and performance, its found that the proposed re-design will pay for itself in just one year, and continue savings for the buildings lifetime.

Lighting loads are usually the greatest load in building. With Standard 90.1, they use a cap of 1.1W/sq. ft. in design. With the existing building, many spaces were well above this figure. After analysis, it was found that using all T5 lamps in the building would save 20% in energy consumption, thus reducing mechanical loads and yearly energy costs.

The construction impact was insignificant since reducing sizes in equipment, this was time was made up by implementing more pumps for the chilled beam CW loop. The only drawback would be finding contractors educated in this field of systems, and not having to pay an extra premium since system in unfamiliar here in the U.S.

IDC Architects designed mechanical system is sufficient. This proposed re-design is an applicable option to the one that already exists. There are many ways to save energy and reduce costs, but most owners are unaware. Awareness of energy use and fossil fuel consumption will allow utilization of new technology and have less impact on the environment.

This senior thesis represents paths of design. Technology updates daily, and it is important that engineers continue their learning beyond the books and educate others along the way. With fossil fuels diminishing, owners need to be aware of energy saving systems. Planning for the future will help ensure a safe environment for our children, along with allowing them to plan for their children and thus keeps the cycle going.

References:

American Society of Heating Air Conditioning and Refrigeration, ed. Handbook of Fundamentals. 2005.

American Society of Heating, Air Conditioning and Refrigeration. Energy Standard for Buildings Except Low-Rise Residential. By ASHRAE, ANSI, and IESNA. Ed. ASHRAE Standard Standing Committee.

Anderson, David. *Technical Assignment #1: ASHRAE Standard 62.1-2004 Ventilation Compliance Evaluation Report.* October 5, 2006.

Anderson, David. *Technical Assignment #2: Building and Plant Energy Analysis Report.* October 27, 2006.

Anderson, David. *Technical Assignment #3: Existing Conditions Evaluation* November 21, 2006.

ANSI/ASHRAE/IESNA Standard 90.1-2004—Energy Standard for Buildings Except Low-Rise Residential Buildings. ASHRAE, Inc. Atlanta, GA. 2004.

ANSI/ASHRAE Standard 62.1-2004—Ventilation for Acceptable Indoor Air Quality. ASHRAE, Inc. Atlanta, GA. 2004

Carrier Corporation. "Hourly Analysis Program v.4.20a." 2004.

Clemson University AMRL—plans and schedules. Construction Issue Set.

"Dedicated Outdoor Air Systems (DOAS)." The Pennsylvania State University. January 18, 2007. <http://doas-radiant.psu.edu/>.

"Electric Service Rate." Duke Power. October 24, 2006. <http://www.dukepower.com/>.

Holophane-Leading in Lighting Solutions. "Controlume Series."Febuary 7, 2007. < http://www.holophane.com >

Mumma, Stanley A, PhD, P.E. "Dedicated Outdoor Air System (DOAS)." Dedicated Outdoor Air Systems. January 18, 2007 < http://doas-radiant.psu.edu/doas.html >.

Mumma, Stanley A, PhD, P.E., and Christopher Conroy. "Ceiling Radiant Cooling Panels as a Viable Distributed Parallel Sensible Cooling Technology Integrated with Dedicated Outdoor Air Systems." **ASHRAE Transactions 2001, Vol. 107 Pt. 1 578-585**). January 18, 2007. < http://doas-radiant.psu.edu/papers >.

Mumma, Stanely A., Ph.D., P.E. "Ceiling Panel Cooling Systems" ASHRAE JOURNAL. 2001. < www.ashrae.org >

"Natural Gas Service Rate." Piedmont Natural Gas. October 24, 2006. < http://www.piedmontng.com/>.

Penn State Architectural Engineering. Rev. of ePortfolio Archives. Architectural Engineering. Dept. home page. 2005. The Pennsylvania State University. January 17, 2007. < http://www.arche.psu.edu/thesis >.

Rumsey, Peter, P.E. "Chilled Beams in Labs- Eliminating Reheat & Saving Energy on a Budget." ASHRAE JOURNAL. January 2007: 18-25.

Thomas, Justin. "Chilled Beams are Cool." January 19, 2007. < http://www.treehugger.com/files/2005/11/chilled_beams_f.php >

Trox Technik. "Active Chilled Beams." January 18, 2007. <http://www.troxusa.com/usa/products/air_water_systems/active_chilled_beams/index.php >

Xetex. "Energy Recovery." January 22. < http://www.xetexinc.com/energy_recovery/index.html >

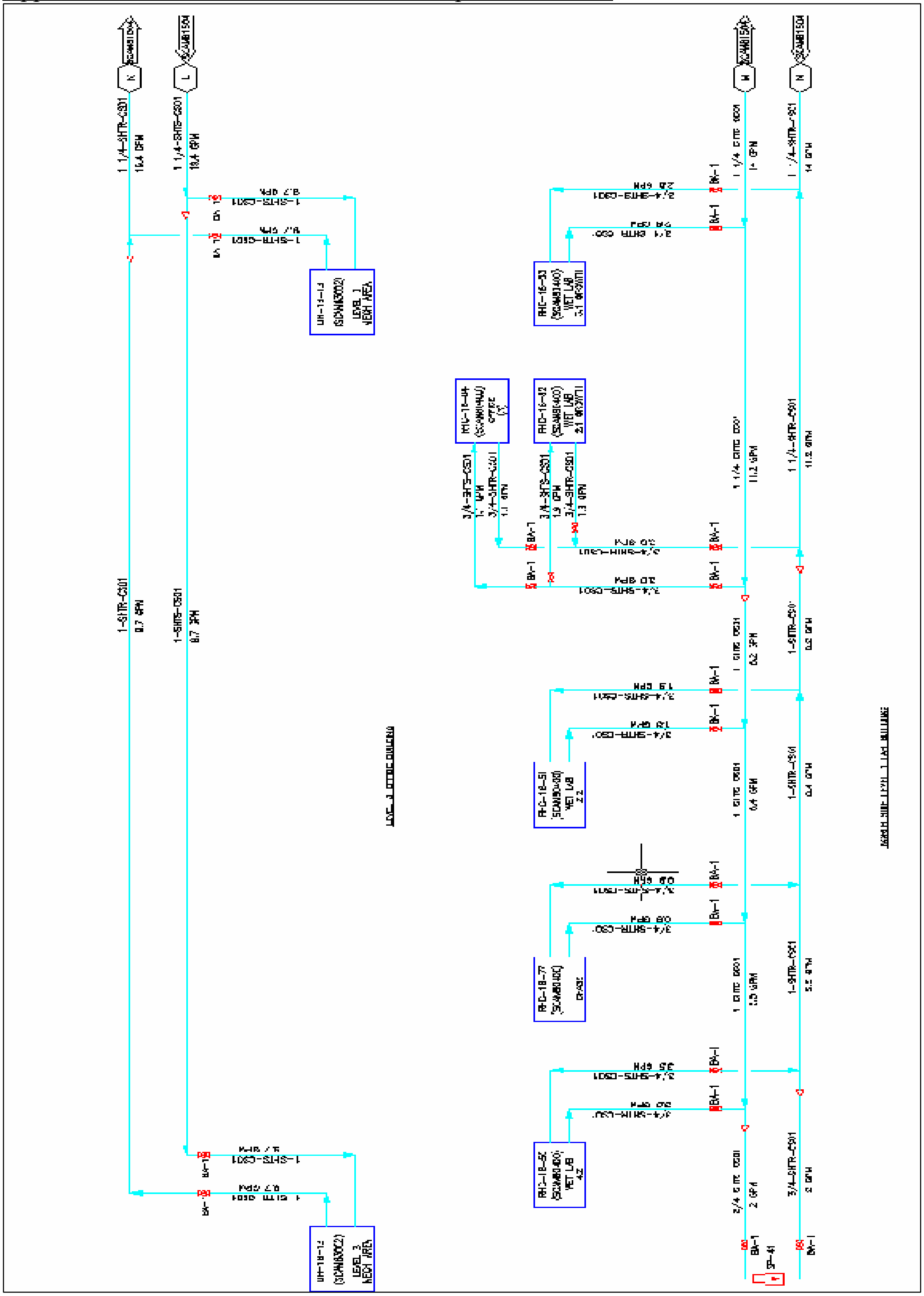
Appendix A: Design Conditions and Calculate V_{ot}

AHU #	Design SA (cfm)	Design OA (cfm)	Calculated Vot (cfm)
1	4000	1800	324
2	4500	1800	257
3	5700	1800	462
4	5200	1800	317
5	6300	6300	1784
6	5800	5550	1784
7	5000	400	399
8	10600	1050	737
9	11300	3350	1167
10	7000	800	561
11	7100	550	600
12	3100	2550	276
13	1600	1100	365
14	1000	300	275
15	6800	2000	253

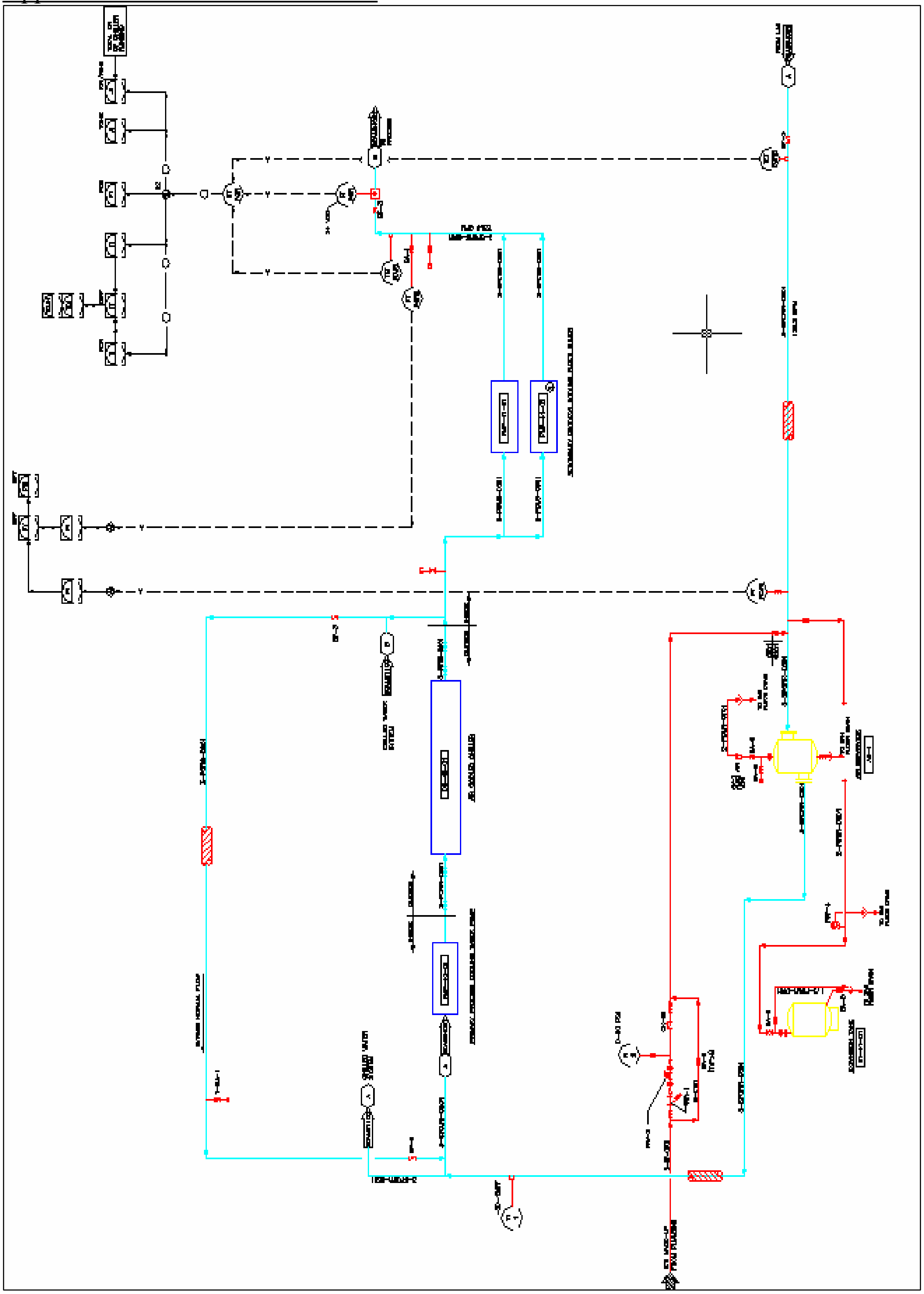
Appendix B: MAH Flow Rate

Unit	CFM
MAH-1	19,525
MAH-2	20,400
MAH-3	20,600
MAH-4	19,150

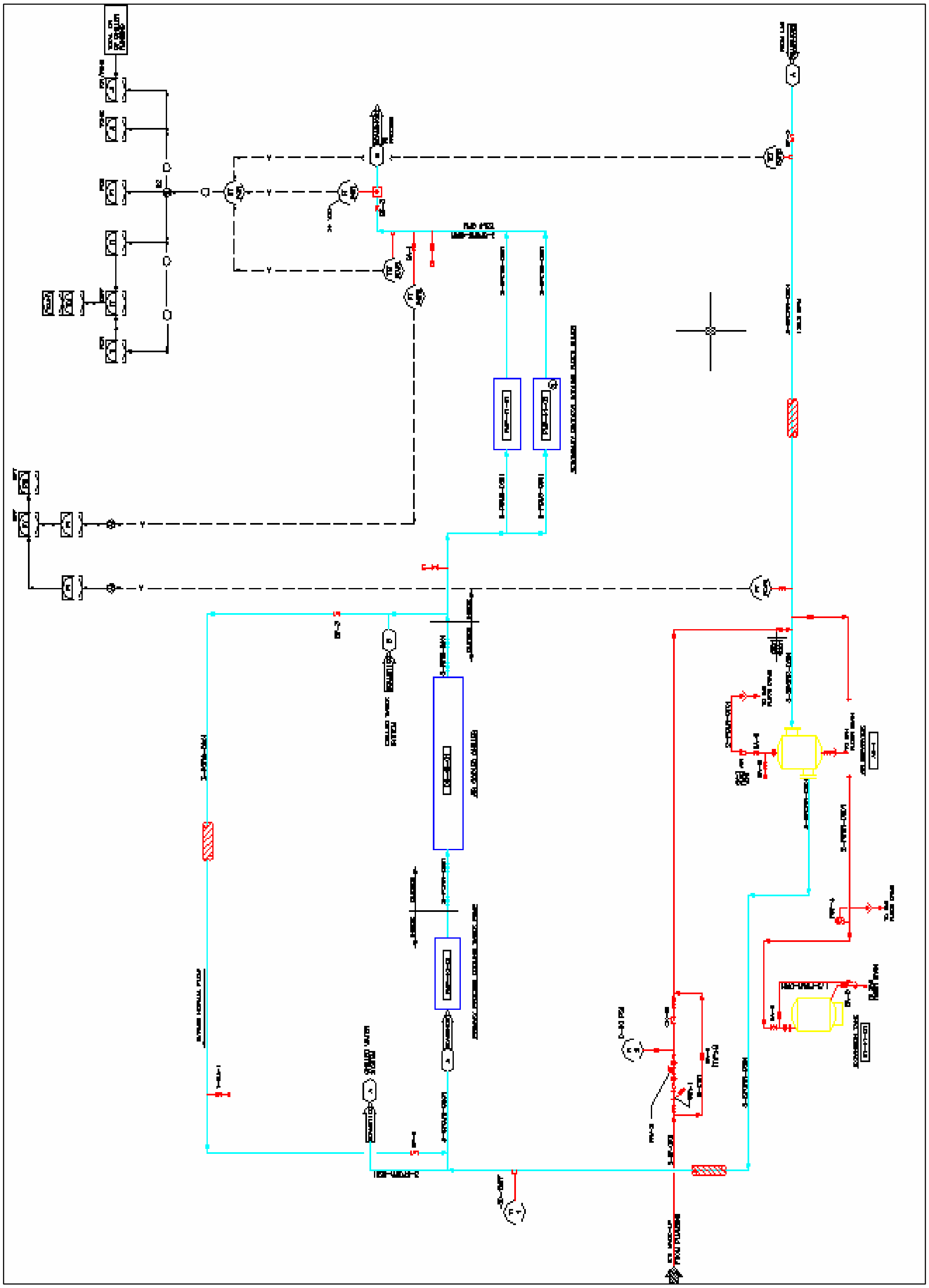
Appendix C: Air Side Schematic For a Sample of 4 AHU's



Appendix D: Hot Water Schematic



Appendix E: Condenser Water Schematic



Appendix F: Q latent Calculations

AHU	# People	kw/person	Q lat (kw)
1	20	0.0586	1.172
2	12	0.0586	0.7032
3	23	0.0586	1.3478
4	20	0.0586	1.172
5	104	0.0586	6.0944
6	104	0.0586	6.0944
7	17	0.0586	0.9962
8	74	0.0586	4.3364
9	23	0.0586	1.3478
10	45	0.0586	2.637
11	44	0.0586	2.5784
12	6	0.0586	0.3516
13	5	0.0586	0.293
14	14	0.0586	0.8204
15	3	0.0586	0.1758
			30.1204
	514	0.0586	30.1204

Appendix G: Table 2-Information Pertinent to the CRCP Cooling Selection

TABLE 2
Information Pertinent to the CRCP Cooling Selection

Column 1	2	3	4	5	6	7
Room design DBT °F (°C)	Room design % RH	Room design DPT °F (°C)	DOAS supply DPT with 20 scfm/person °F (°C)	Panel t_{fi} room DPT+3°F °F (°C)	Mean panel temp. assuming t_{fi}+5°F °F (°C)	Q_s, Btu/h·ft² (W/m²)
72 (22)	40	46 (8)	37 (3)	49 (9)	54 (12)	30 (95)
72 (22)	60	57 (14)	51 (11)	60 (16)	65 (18)	10 (32)
78 (26)	40	52 (11)	44 (7)	55 (13)	60 (16)	30 (95)
78 (26)	60	63 (17)	58 (14)	66 (19)	71 (22)	10 (32)

Appendix H: Table 9.5.1 Lighting Power Densities Using the Building Area Method

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	Lighting Power Density (W/ft2)
Automotive Facility	0.9
Convention Center	1.2
Court House	1.2
Dining: Bar Lounge/Leisure	1.3
Dining: Cafeteria/Fast Food	1.4
Dining: Family	1.6
Dormitory	1.0
Exercise Center	1.0
Gymnasium	1.1
Health Care-Clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing Facility	1.3
Motel	1.0
Motion Picture Theater	1.2
Multi-Family	0.7
Museum	1.1
Office	1.0
Parking Garage	0.3
Penitentiary	1.0
Performing Arts Theater	1.6
Police/Fire Station	1.0
Post Office	1.1
Religious Building	1.3
Retail	1.5
School/University	1.2
Sports Arena	1.1
Town Hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

[a] In cases where both general building area type and a specific building area type are listed, the specific building area type shall apply.

Appendix I: First Cost Example of DOAS vs. VAV

Cost item	Unit Cost	Units VAV	Units Panel-Cooling/DOAS	Cost Savings $
Chiller	\$1,000/ton (\$284/kW)	506 ton (1780 kW)	306 ton (1076 kW)	200,000
Chilled Water Pump	\$25/gpm (\$400/L/s)	1215 gpm (76.5 L/s)	737 gpm (46.4 L/s)	11,950
Ductwork	\$1/ ft² (\$11/m²) DOAS \$4/ ft² (\$43/m²) VAV	186,000 ft² (17 300 m²)	186,000 ft² (17 300 m²)	558,000
AHU	\$2/cfm (\$4.25/L/s) VAV \$4/cfm (\$8.50/L/s) DOAS	135,000 cfm (73 720 L/s)	25,000 cfm (11 800 L/s) 100% Ventilation Air	170,000
Electrical Service	\$50/kW	630 kW	372 kW	12,400
Facade/Partitions	\$35/ft² (\$376/m²) of Facade	No Depth Reduction	1 ft (0.3 m) Plenum Depth/Floor or 4308 ft² (400 m²)	150,780
Integrated Thermal and Fire Suppression Piping	\$0.65/ft² (\$7/m²) Savings	N/A	186,000 ft² (17 300 m²)	120,900
Drop Ceiling	\$1.50/ft² (\$16/m²)	N/A	79,200 ft² (7365 m²)	118,800
Mechanical Shaft Impact on Lost Rental Space	\$125/ ft² (\$1,344/m²)	N/A	500 ft² (47 m²) Saved	62,500
Savings Subtotal				**1,405,300**
Panel	\$13/ ft² (\$140/m²) of Panel	N/A	79,200 ft² (7365 m²)	–1,029,600
Net Savings				**375,700 or 2/ft² (22/m²)**

Table 1: First cost comparison of the panel-cooling/DOAS vs. a conventional all-air VAV system serving a six-story 186,000 ft² (17 300 m²) building in Philadelphia.

Appendix J: Cut Sheets for Enthalpy Wheel

AIRotor
by XeteX

Air-to-Air Heat Recovery

XeteX Inc.
3530 East 28th Street
Minneapolis, MN 55406
(612) 724-3101
(612) 724-3372 Fax

AIRotor

General

The AIRotor heat recovery unit is a rotary heat exchanger which operates on the air-to-air principle of heat transfer and has the following features:

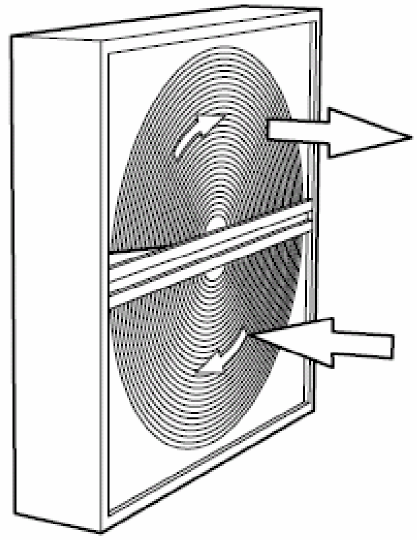
- Available in 16 sizes, with a nominal flow range of 500-28,000 cfm.
- Total energy recovery efficiencies as high as 90%.
- Rotor has smooth air channels to ensure a low pressure drop and reduce the risk of fouling.
- Rotor surface is manufactured absolutely smooth allowing for tight fitting seals between airstreams.
- Available with electronic speed control for variable rotor capacity.
- Hygroscopic rotor provides latent and sensible heat recovery.

Design

The RVA heat recovery unit is constructed from a rigid tubular steel welded frame, with insulated galvanized sheet metal cover plates and hatches. The frame is reinforced to prevent deflect of the rotor from static pressure drops to less than 0.03".

The rotor is assembled from alternate layers of flat and corrugated thin sheet aluminum. The smooth channels formed by this construction ensure that the air flow is laminar, thereby ensuring that the pressure drop is low and minimizing the risk of fouling by dirt or dust. Dry particles up to 900 microns shall pass freely through the rotor without clogging the media. The rotor media can be cleaned with low temperature steam without degrading unit performance.

The hygroscopic rotor equally transfers both sensible and latent heat. Moisture is transferred between airstreams in the vapor stage so media remains dry and no drain pan is required.



The rotor, which may be removed from the frame, is mounted in sealed permanently-lubricated spherical ball bearings. The bearings can be serviced or replaced without removing the rotor from the case.

The exchanger is sealed with brush seals between airstreams and around the perimetor of the rotor. Because of the the smooth rotor surface, the brush seals provides an extremely effective seal with very little contact pressure, resulting in extended service life.

An adjustable purging sector is provided to ensure continuous cleaning of the rotor and to virtually eliminate cross-contamination between the exhaust air the supply air.

The standard AIRotor heat recovery unit is supplied with a perimeter self adjusting drive belt and worm gear drive for on/off operation.

For installations where there is a requirement for controlling heat recovery capacity and/or rotor frost control, the heat recovery unit is equipped with an electronic control unit that varies rotor speed from maximum speed down to an automatic purge cycle of 1/20 rpm.

Specifications and dimensions are subject to change without notice.

2

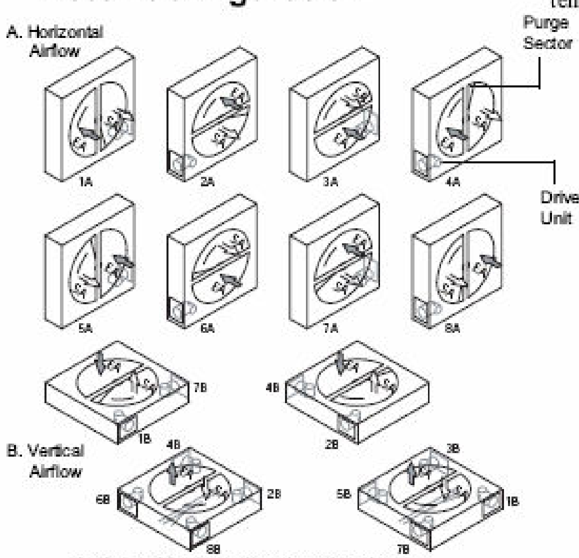
AIRotor

Specification

HRW RV(X)-a-b-c-d-e-f

RVB	0600, 0700, 0850, 1000, 1160	a
RVA	0600, 0700, 0850, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 2750, 3000	a
Rotor Type	No = Non Hygros. Hy = Hygroscopic	b
Drive Unit	K = Constant Speed R = Electronic Speed Control (ESC)	c
Purge Sector	0 = Without 1 = With	d
Unit Config.	1, 2, 3, 4, 5, 6, 7, 8 (See Below)	e
Air Flow	A = Horizontal B = Vertical	f

Rotor Configuration



Specifications and dimensions are subject to change without notice.

Accessories

RVAT-x-x-x-x

Flanged Duct Connections	01
Epoxy Treated Rotor	02
Filter Sections	
2" Pleated	03
Washable Filters	04

Control Options

Constant Speed Drive

Speed Detector (w/Alarm Contact) (Standard with Elect. Spd Control) 05

Electronic Speed Control

Frost Control	06
Economizer Control	07
Summer Changeover	08

Description of Controls

Frost Control monitors the exhaust temperature leaving exchanger and reduces rotor speed to prevent exhaust temperature from dropping below setpoint.

Economizer control monitors supply discharge temperature and reduces rotor speed to prevent discharge from rising above setpoint.

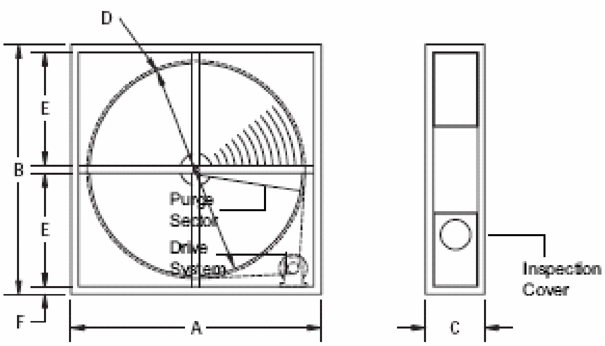
Summer Changeover control monitors outdoor air and return air temperatures and automatically switches rotor to maximum recovery speed when the outside air temperature is higher then the return air temperature.

3

AIRotor

TECHNICAL SPECIFICATIONS

Dimensions and Weights



MODEL #	DIMENSIONS						WEIGHT (lbs)
	A	B	C	D	E	F	
RVB-0600	24.43	31.00	14.25	18.90	14.10	0.70	90
RVB-0700	31.00	31.00	14.25	23.23	14.10	0.70	155
RVB-0850	36.00	36.00	14.25	29.13	16.60	0.70	190
RVB-1100	43.60	43.60	14.25	37.50	20.40	0.70	265
RVC-1300	53.54	54.72	14.96	46.46	22.25	1.58	350
RVC-1600	62.05	63.23	14.96	57.09	27.00	1.58	440
RVC-1900	76.77	77.95	14.96	70.87	32.10	1.58	640
RVC-2100	85.04	86.22	14.96	78.35	37.00	1.58	735
RVA-2250	88.58	88.58	17.32	81.10	40.75	2.36	880
RVA-2500	98.74	98.74	17.32	90.94	45.67	2.36	1035
RVA-2750	108.58	108.58	17.32	100.79	50.59	2.36	1210
RVA-3000	118.43	118.43	17.32	110.63	55.51	2.36	1365

AIRotor Drive System

AIRotors are driven with a belt around the perimeter of the rotor. An AC gear reduced motor with permanently sealed bearings is easily serviced through an access panel in the corner of the wheel housing. A spare belt can be provided with each wheel to reduce downtime in the event of belt failure.

Constant Speed Drive

The AIRotor constant speed drive is provided with On/Off dry contacts for control by a thermostat or building control system. An optional speed detector is available which closed a normally open contact when wheel stops turning for over 20 minutes.

Electronic Speed Control

The AIRotor Electronic speed control consists of a motor control center and drive motor. The control center incorporates functions for purging, speed detection, motor protection and alarm. For speed control the control center is built to receive 0-10 VDC or 4-20 mA input from temperature controller.

Frost, Economizer, & Summer/ Winter Changeover Control

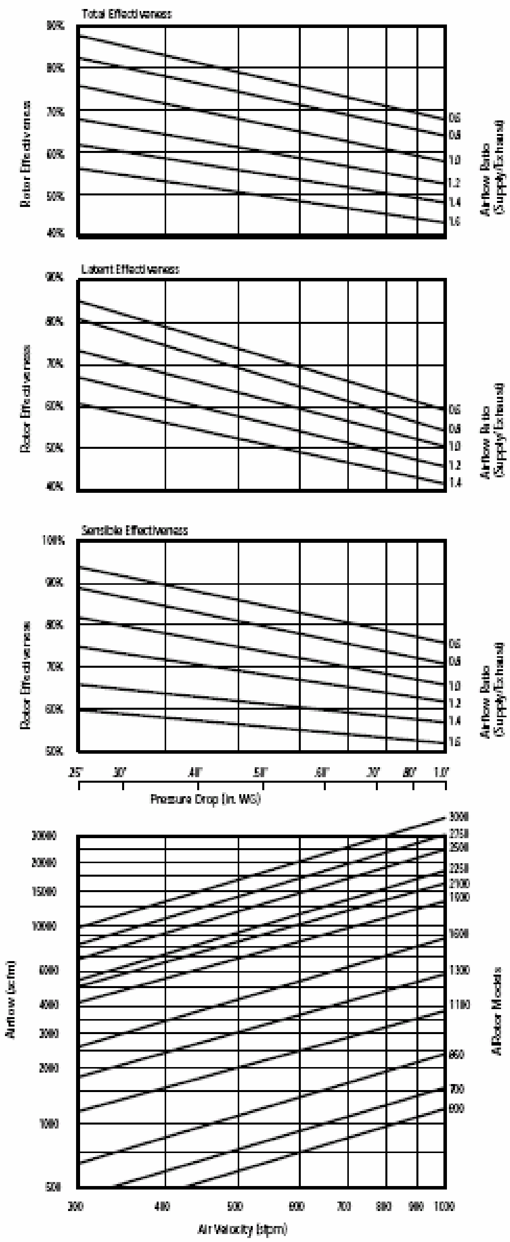
The AIRotor can be supplied with built-in temperature controller that automatically modulates rotor speed to prevent frost build-up, reduce heat recovery to prevent overheating space (economizer), and switch to maximum recovery during the summer (W/S Changeover). AIRotor is supply with integral control panel, digital temperature readout, and four remote mounted temperature sensors.

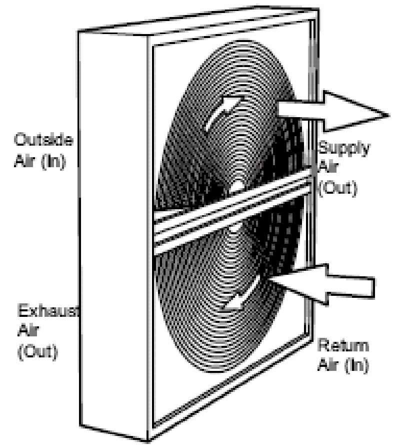
Specifications and dimensions are subject to change without notice.

4

AIRotor

PERFORMANCE CHARTS



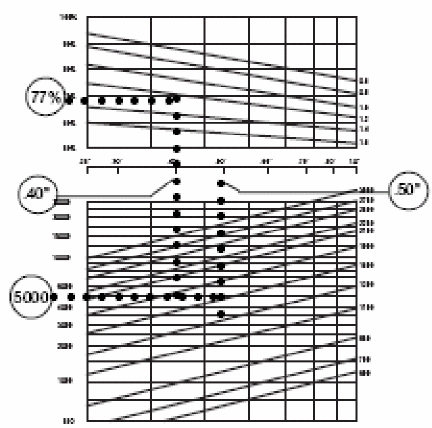


Example

Given the following conditions:
Supply Airflow = 5000 cfm
Return Airflow = 5000 cfm
Maximum Pressure Drop = 0.5" WG

Select AIRotor 1750

From the charts:
Pressure Drop = 0.40"
Effectiveness = 77%



Specifications and dimensions are subject to change without notice.

5

AIRotor

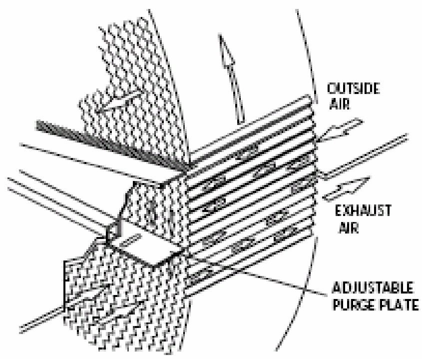
PURGING AND LEAKAGE AIRFLOW

In rotary heat exchangers a certain amount of leakage inevitably takes place, in both directions, between the supply air and exhaust air sides, the leakage air being transferred by the rotor.

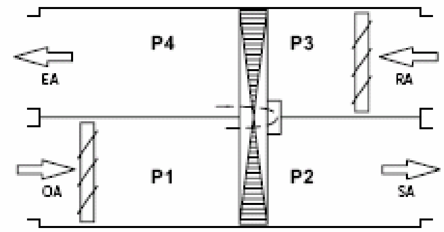
The purging sector is used to clean the rotor to eliminated leakage from the exhaust air to the supply air side. A detail of the purge sector is shown below.

When installing a unit provided with a purging sector, the fans should be located so that P1 > P4 and P2 > P3, as shown in the figure below. If required, an adjusting damper may be used to obtain the required pressure balance.

The chart below shows the leakage flow throught the purging sector. Allowance for high differential pressures should be made when selecting the fan.



Purge Sector Detail

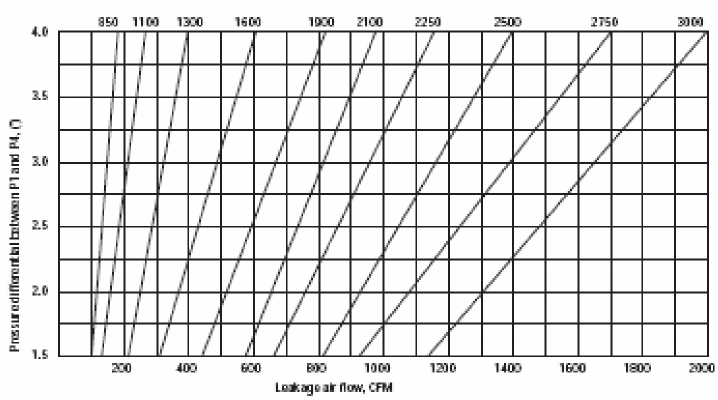


Purge Schematic

Purge Airflow Chart

AIRotor Model

Approximate leakage through the purging sector and seals
HYGROSCOPIC ROTOR @ 20 RPM



Specifications and dimensions are subject to change without notice.

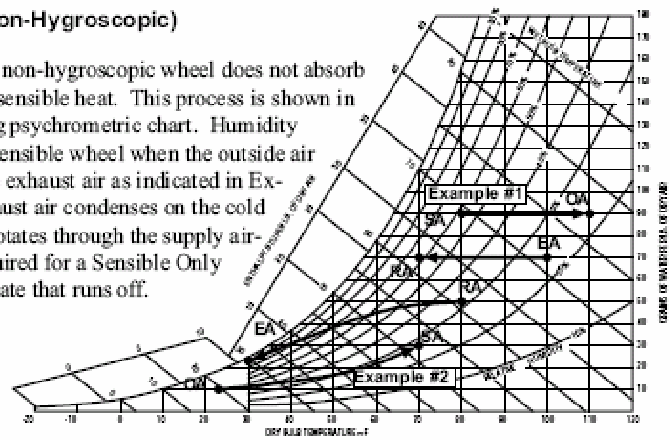
6

AIRotor

PSYCHROMETRIC ANALYSIS

Sensible Only Wheel (Non-Hygroscopic)

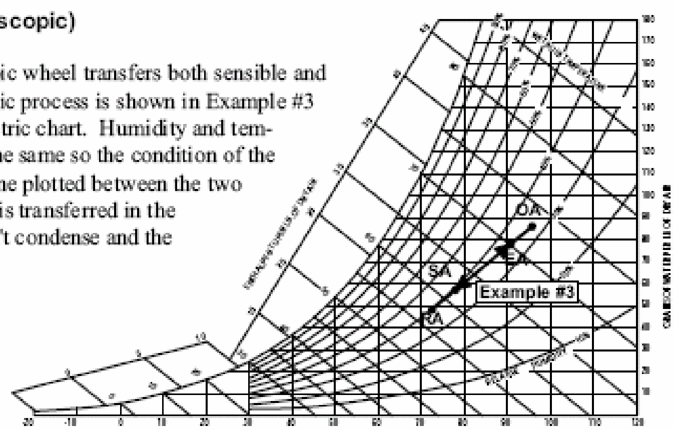
The Sensible Only wheel or non-hygroscopic wheel does not absorb moisture and transfers only sensible heat. This process is shown in Example #1 on the adjoining psychrometric chart. Humidity transfer only occurs with a sensible wheel when the outside air is below the dewpoint of the exhaust air as indicated in Example #2. The warmer exhaust air condenses on the cold wheel and evaporates as it rotates through the supply airstream. A drain pan is required for a Sensible Only wheel to collect the condensate that runs off.



SA = Supply Air
RA = Return Air
OA = Outside Air
EA = Exhaust Air

Enthalpy Wheel (Hygroscopic)

The Enthalpy or Hygroscopic wheel transfers both sensible and latent heat. This hygroscopic process is shown in Example #3 on the adjoining psychrometric chart. Humidity and temperature effectiveness are the same so the condition of the air varies along a straight line plotted between the two inlet conditions. Humidity is transferred in the vapor stage so the air doesn't condense and the wheel stays dry.



Specifications and dimensions are subject to change without notice.

7

GENERAL SPECIFICATION

ROTARY AIR-TO-AIR HEAT EXCHANGER

Furnish an "AIRotor" rotary air-to-air heat exchanger manufactured by XeteX, Inc. Exchanger shall include hygroscopic rotor, constant or variable speed drive, rotation detector with alarm connection, and speed controller with temperature sensors.

ENTHALPY RECOVERY WHEEL

Exchanger shall be constructed of alternate Layers of corrugated and flat aluminum sheet material. Both sides of the exchanger shall be completely smooth with less then 0.005" variation between alternate layers to allow for optimum sealing surface for brush seals. The rotor shall have smooth air channels to ensure laminar airflow for low pressure drops. Dry particles up to 900 microns shall pass freely through the rotor without clogging the media. The rotor media shall be capable of being cleaned with low temperature steam without degrading unit performance. The rotor media must be made of aluminum which is coated to prohibit corrosion. All surfaces shall be coated with a nonmigrating adsorbent specifically developed for the selective transfer of water vapor.

* Verification in writing must be presented from independent laboratory evaluations confirming that the desiccant adsorbent surface does freely transmit water vapor without detectable gaseous cross-contamination. Specially formulated aluminum compound of "Micro-Sieve" shall permanently bond the selective adsorbent desiccant to the hygroscopic (enthalpy) recovery AIRotor by XeteX.

* Sensible and latent recovery efficiencies must be clearly documented through a certification program conducted in accordance with ASHRAE 84-1991 and ARI 1060 standards that verify actual performance to be *indepen-dent phenomena and there is no reason to expect that ...(efficiencies)... will be equal.* Performance is derived by assuming equal sensible and latent recovery effectiveness.

UNIT HOUSING

The rotor housing shall be constructed using a heavy duty welded tubular steel frame (rotors under 42" shall have a heavy duty galvanized frame) with galvanized sheet metal cover plates and inspection hatches. Adjustable brush seals must be provided along the periphery of the rotor and between the inlet and outlet air passages to effectively prevent air leakage and cross-contamination between airflows. Total air flow between airstreams from leakage and purge shall be less than 10% @ 2.5"w.g. differential pressure between airflows. Rotor and casing shall be reinforced to prevent deflection from differential pressures to less than .03 inches. All rotors shall be mounted on sealed permanently-lubricated spherical bearings. All rotors over 42" in diameter must have flanged or pillow block bearings that can be serviced or replaced without removal of the rotor from the rotor housing.

PURGE SECTOR

* The unit must be provided with a factory set, field adjustable purge sector designed to limit cross contamination at qualified appropriate design conditions to operate at less than .04 percent of that of the exhaust air stream concentration. Independent laboratory evaluations must indicate purge sector configurations, rotor construction, gasses, air pressure differentials, rotor speeds and other phenomena that constitute "appropriate design conditions" required to limit cross-contamination and air leakage.

DRIVE SYSTEM/SPEED CONTROL

The rotor drive system shall consist of a self adjusting belt around the rotor perimeter driven by an AC motor with gear reduction. The variable speed drive shall be specifically designed for heat wheel applications to include: an AC inverter, soft start/stop, rotation detection w/alarm contacts, automatic self cleaning jog cycle, and self testing capability. The speed controller shall be capable of accepting any control signal (potentiometer, VDC, and mA).

AUTOMATIC TEMPERATURE CONTROL

The temperature control system shall consist of an integral control panel with remote temperature sensors mounted in each of the four airstreams to monitor exchanger performance. The control shall modulate rotor speed to (1) prevent frost build-up, (2) reduce heat recovery for economizer mode, (3) switch to maximum heat recovery when outdoor temperature is higher than indoor temperature. A rotation detector/alarm shall be built into control panel with contactor provided for connection building control system.

*** Refer to independent performance tests of XeteX AIRotor Total Energy Recovery Wheels conducted, evaluated and verified for the specified characteristics by research assistants from the Department of Mechanical Engineering, University of Minnesota, Minneapolis. Detailed Technical Reports that certify Thermal Effectiveness and Cross-Contamination performance are available on request.**

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Form 2.2E04 01 Printed in USA

Appendix K: Cut Sheets for Chilled Beams

Description · Construction

Description

Active chilled beams type DID300 use a combination of air and water systems. They combine the air flow characteristics of ceiling diffusers with the energy benefits of load dissipation using water.
The primary volume flow required for fresh air is supplied through a duct into which nozzles are fitted.
As a result secondary room air is induced through vertical water coils.
In the mixing section of the type DID300 the conditioned secondary air is mixed with the primary air and discharged into the room via slots. The type DID300 can be used for cooling and/or heating.
Optionally a condensation tray can be provided below each coil. If the room dew point temperature is reached resultant condensation is trapped in the trays. Two drainage spigots are provided with locking caps. If necessary the caps can be removed on site to drain the condensate.

Caution!
In the version without condensation drip trays, the chilled water flow temperature should be selected to prevent it from falling below the room dewpoint.

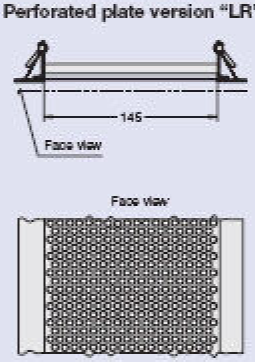
Construction

The type DID300 is particularly suitable for use in low ceiling void spaces because of its shallow construction. Thus the type DID300 is not only suitable for new buildings but is also ideal for refurbishment projects.
When connected appropriately they can be used for individual room control or form grouped zone control.
Control components (valves) are available on request.

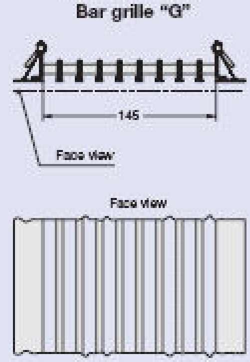
Despite the small primary air volumes the use of a coil with the energy medium of water gives a disproportionately high cooling and heating performance.
The standard type DID300 is constructed as a 2-pipe or 4-pipe system.
The discharge nozzles in the primary air duct are available in three different sizes, selection depending on volume flow rates.

The induction path grille can be supplied either in a perforated or bar grille format.
Because of the variety of possible ceiling systems, options are available for integration into various ceilings.

Induction grille
Perforated plate version "LR"



Induction grille
Bar grille "G"



2

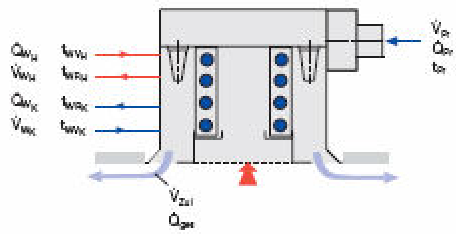
Performance overview DID300 – cooling

L_N = 1200 mm, 1500 mm, 1800 mm

Reference values

t_{WVK} = 16 °C: Water flow temperature, cooling
t_{Pr} = 16 °C: Primary air temperature
$\dot{V}_{WK}$ = 110 l/h: Water volume flow rate, cooling

$\dot{V}_{Zul}$ in l/s: Supply air volume flow rate
$\dot{V}_{Pr}$ in l/s: Primary air volume flow rate
$\dot{Q}_{ges}$ in Watt: Total cooling capacity $\dot{Q}_{Pr} + \dot{Q}_S$
$\dot{Q}_{Pr}$ in Watt: Cooling capacity of the primary air
$\dot{Q}_S$ in Watt: Cooling capacity of the secondary air
$\dot{q}_{Zul}$ in W/m²: Specific cooling capacity
Δp_t in Pa: Primary air pressure drop
Δp_w in kPa: Water pressure drop
L_{WA} in dB(A): A-weighted sound power level
$\bar{v}_L$ in m/s: Time average air velocity



See pages 18, 19, 20 and 21 for selection example

2-pipe system

Table 1:
L_N = 1200 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	14	70	136	270	406	54	1.9	37	95	2.2
B	20	79	194	291	484	65	2.7	35	72	2.2
C	25	89	252	281	532	71	3.5	39	59	2.2

Room air temperature t_R = 26 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	14	70	169	339	508	68	1.9	37	95	2.2
B	20	79	241	363	604	81	2.7	35	72	2.2
C	25	89	314	351	664	88	3.5	39	59	2.2

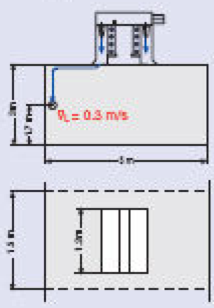


Table 2:
L_N = 1500 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	16	80	155	312	466	52	1.9	33	98	2.6
B	24	94	232	343	576	64	2.7	35	82	2.6
C	32	102	310	336	646	72	3.5	38	68	2.6

Room air temperature t_R = 26 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	16	80	193	389	582	65	1.9	33	98	2.6
B	24	94	289	429	719	80	2.7	35	82	2.6
C	32	102	385	421	806	90	3.5	38	68	2.6

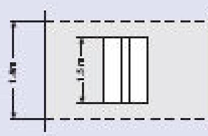
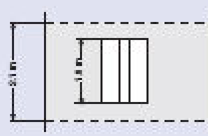


Table 3:
L_N = 1800 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	19	95	194	351	545	52	1.9	35	106	3.0
B	25	101	252	379	630	60	2.5	36	74	3.0
C	34	109	329	357	685	65	3.2	38	59	3.0

Room air temperature t_R = 26 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	19	95	229	451	680	65	1.9	35	106	3.0
B	25	101	314	473	786	75	2.5	36	74	3.0
C	34	109	410	459	869	83	3.2	38	59	3.0



4-pipe system

Table 4:
L_N = 1200 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	14	70	136	246	382	51	1.9	37	95	1.7
B	20	79	194	265	459	61	2.7	35	72	1.7
C	25	89	252	256	508	68	3.5	33	55	1.7

Room air temperature t_R = 26 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	14	70	169	308	477	64	1.9	37	95	1.7
B	20	79	241	332	573	76	2.7	35	72	1.7
C	25	89	314	320	634	84	3.5	33	55	1.7

Table 5:
L_N = 1500 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	16	80	155	285	440	49	1.9	33	98	2.0
B	24	94	232	314	547	61	2.7	35	82	2.0
C	32	102	310	309	619	69	3.5	38	68	2.0

Room air temperature t_R = 26 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	16	80	193	356	549	61	1.9	33	98	2.0
B	24	94	289	393	682	76	2.7	35	82	2.0
C	32	102	385	385	771	85	3.5	38	68	2.0

Table 6:
L_N = 1800 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	19	95	194	321	515	49	1.9	35	106	2.5
B	25	101	252	347	599	57	2.5	36	74	2.5
C	34	109	329	356	685	63	3.2	38	59	2.5

Room air temperature t_R = 26 °C

Nozzle type	$\dot{V}_{Pr}$ l/s	$\dot{V}_{Zul}$ l/s	$\dot{Q}_{Pr}$ Watt	$\dot{Q}_S$ Watt	$\dot{Q}_{ges}$ Watt	$\dot{q}_{Zul}$ W/m²	$\dot{V}_{Zul}$/m² l/(s·m²)	L_{WA} dB(A)	Δp_t Pa	Δp_w kPa
A	19	95	229	413	642	61	1.9	35	106	2.5
B	25	101	314	434	747	71	2.5	36	74	2.5
C	34	109	410	480	890	79	3.2	38	59	2.5

11

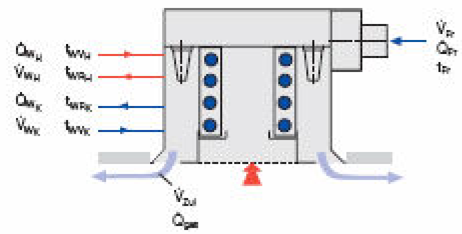
Performance overview DID300 – cooling

L_N = 2100 mm, 2400 mm, 2700 mm, 3000 mm

Reference values

t_{WK} = 16 °C: Water flow temperature, cooling
t_{Pr} = 16 °C: Primary air temperature
$\dot V_{WK}$ = 210 l/h: Water volume flow rate, cooling

$\dot V_{Zul}$ in l/s: Supply air volume flow rate
$\dot V_{Pr}$ in l/s: Primary air volume flow rate
$\dot Q_{ges}$ in Watt: Total cooling capacity $\dot Q_{Pr} + \dot Q_S$
$\dot Q_{Pr}$ in Watt: Cooling capacity of the primary air
$\dot Q_S$ in Watt: Cooling capacity of the secondary air
q_{Zul} in W/m²: Specific cooling capacity
Δp_L in Pa: Primary air pressure drop
Δp_W in kPa: Water pressure drop
L_{WA} in dB(A): A-weighted sound power level
$\bar v_L$ in m/s: Time average air velocity



2-pipe system

Table 7:
L_N = 2100 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	22	110	219	472	691	58	1.8	30	109	10.1
B	31	121	300	510	810	68	2.6	32	79	10.1
C	41	131	397	497	894	75	3.4	33	64	10.1

Room air temperature t_R = 26 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	22	110	265	587	853	72	1.8	30	109	10.1
B	31	121	374	638	1012	84	2.6	32	79	10.1
C	41	131	494	622	1116	93	3.4	33	64	10.1

Table 8:
L_N = 2400 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	25	125	242	535	777	58	1.8	32	109	11.3
B	34	139	329	560	889	68	2.5	33	75	11.3
C	46	147	446	552	998	74	3.4	35	63	11.3

Room air temperature t_R = 26 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	25	125	301	669	970	72	1.8	34	109	11.3
B	34	139	410	699	1109	82	2.5	33	75	11.3
C	46	147	555	690	1245	92	3.4	35	63	11.3

Table 9:
L_N = 2700 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	28	140	271	589	860	57	1.8	34	110	12.5
B	39	152	377	624	1002	57	2.6	35	80	12.5
C	52	166	503	612	1115	74	3.5	36	68	12.5

Room air temperature t_R = 26 °C

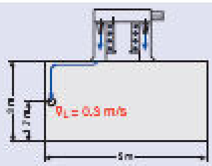
Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	28	140	338	737	1074	72	1.8	34	110	12.5
B	39	152	470	780	1251	83	2.6	33	80	12.5
C	52	166	627	765	1392	93	3.5	36	68	12.5

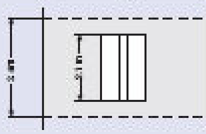
Table 10:
L_N = 3000 mm
Room air temperature t_R = 24 °C

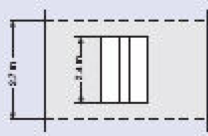
Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	31	155	300	642	942	57	1.8	35	112	13.6
B	42	164	407	670	1076	66	2.5	35	78	13.6
C	60	182	591	661	1251	76	3.6	39	72	13.6

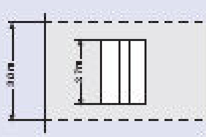
Room air temperature t_R = 26 °C

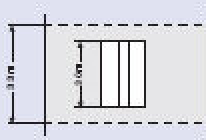
Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	31	155	374	803	1177	71	1.8	35	112	13.6
B	42	164	506	837	1344	81	2.5	35	78	13.6
C	60	182	723	851	1574	95	3.6	39	72	13.6











4-pipe system

Table 11:
L_N = 2100 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	22	110	213	436	649	54	1.8	30	109	7.7
B	31	121	303	463	766	64	2.6	32	79	7.7
C	41	131	397	454	851	71	3.4	33	64	7.7

Room air temperature t_R = 26 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	22	110	265	545	810	67	1.8	30	109	7.7
B	31	121	374	582	956	80	2.6	32	79	7.7
C	41	131	494	567	1062	88	3.4	33	64	7.7

Table 12:
L_N = 2400 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	25	125	242	488	730	54	1.8	32	109	6.6
B	34	139	329	511	840	62	2.5	33	75	6.6
C	46	147	445	505	950	70	3.4	35	63	6.6

Room air temperature t_R = 26 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	25	125	301	610	912	66	1.8	32	109	6.6
B	34	139	410	639	1049	76	2.5	33	75	6.6
C	46	147	555	631	1185	88	3.4	35	63	6.6

Table 13:
L_N = 2700 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	28	140	271	539	810	54	1.8	34	110	9.5
B	39	152	377	571	949	62	2.6	35	80	9.5
C	52	169	503	560	1063	71	3.5	36	68	9.5

Room air temperature t_R = 26 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	28	140	338	674	1011	67	1.8	34	110	9.5
B	39	152	470	714	1185	79	2.6	35	80	9.5
C	52	169	627	700	1327	88	3.5	36	68	9.5

Table 14:
L_N = 3000 mm
Room air temperature t_R = 24 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	31	155	300	599	899	54	1.8	35	112	10.3
B	42	164	407	614	1021	62	2.5	35	78	10.3
C	60	182	581	624	1205	73	3.6	39	72	10.3

Room air temperature t_R = 26 °C

Nozzle type	$\dot V_{Pr}$ l/s	$\dot V_{Zul}$ l/s	$\dot Q_{Pr}$ Watt	$\dot Q_S$ Watt	$\dot Q_{ges}$ Watt	q_{Zul} W/m²	$\dot V_{Zul}$/m² l/(s m²)	L_{WA} dB(A)	Δp_L Pa	Δp_W kPa
A	31	155	374	735	1109	67	1.8	35	112	10.3
B	42	164	505	769	1274	77	2.5	35	78	10.3
C	60	182	723	780	1503	91	3.6	39	72	10.3

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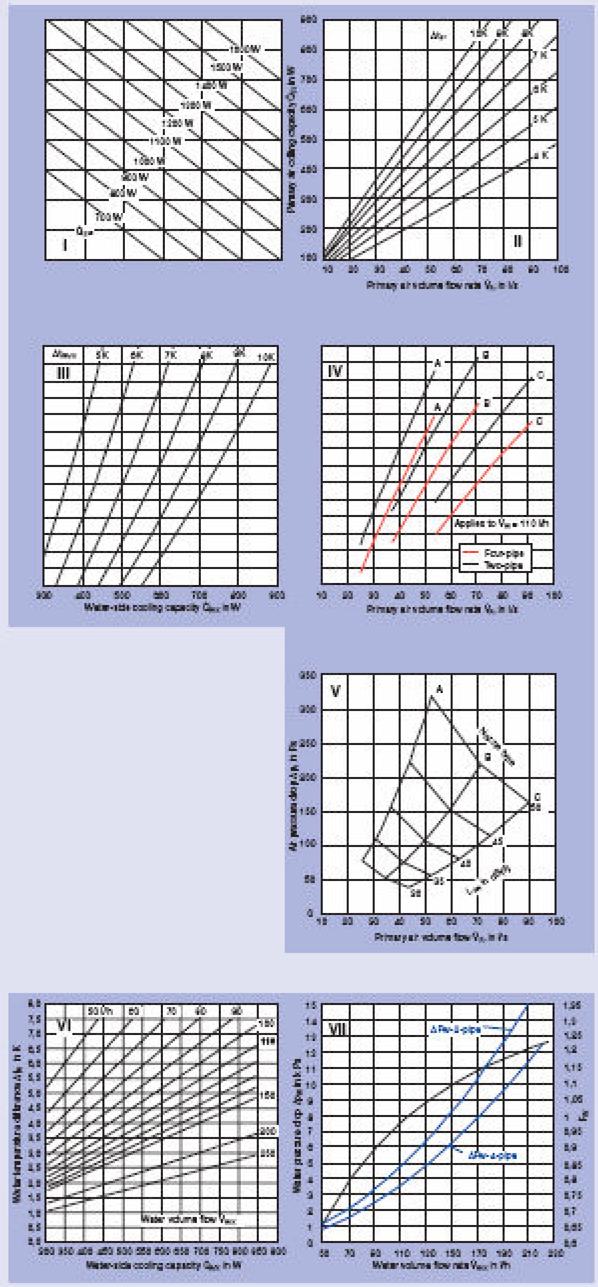
Technical data – cooling DID300 L_N = 3000

Correction factor K_{fs} free cross-sectional area DID300 face section L_N 3000 mm			
Free area = 50% Primary air V_{Pr} in l/s	Nozzle type A	Nozzle type B	Nozzle type C
25	0.90		
40	0.95	0.95	
60	0.97	0.97	0.94
70		0.97	0.94
90			0.95
Free area = 70% Primary air V_{Pr} in l/s	Nozzle type A	Nozzle type B	Nozzle type C
25-90	1		



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Aerodynamic data

DID300 $L_N = 3000$

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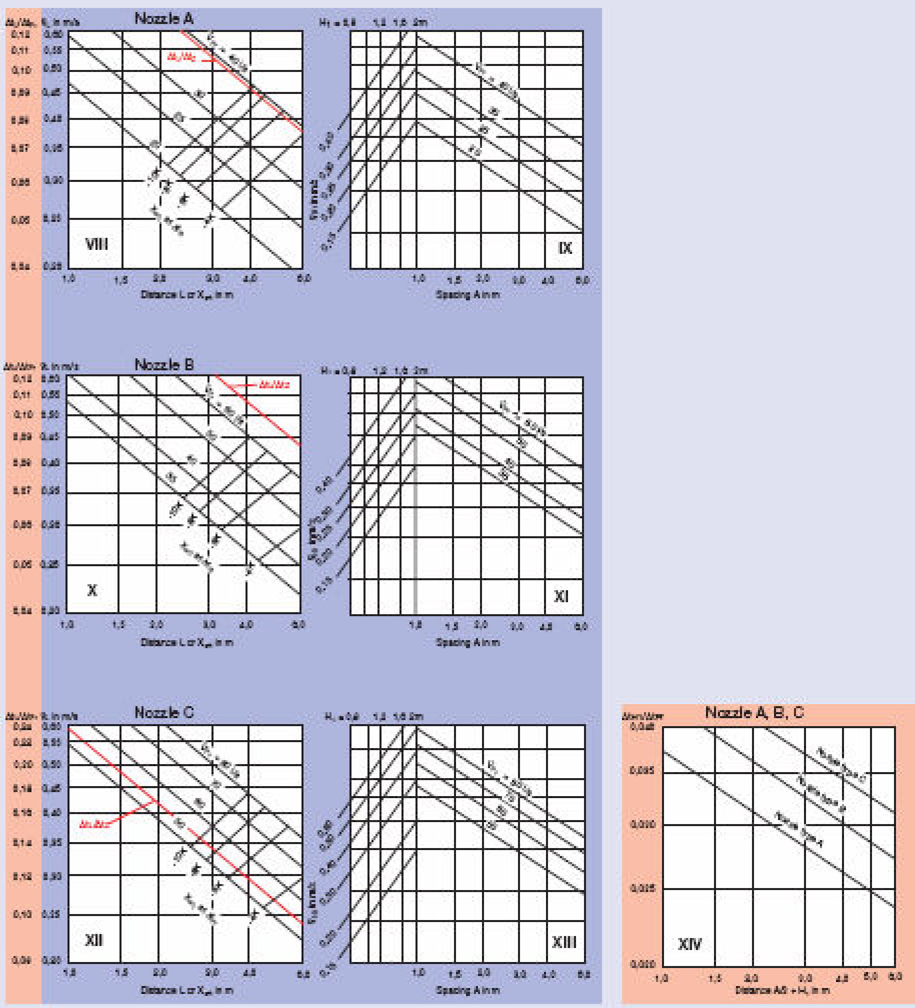
The details on scope of delivery appearance, performance as well as weights and measures are valid at the time of the printing of this brochure and they are subject to change at any time. All previous releases are now superseded.



Order Details

Specification text

The active chilled beam type DID300 suitable for dealing with high internal thermal loads using a combination of air and water comprises a casing with integral primary air duct fitted with two sets of induction nozzles size related to primary air flow rate. Below the primary air duct two coils which can optionally be fitted with condensate trays. The induction grille below the coils can be either a perforated plate or a bar grille. The coils can be used either for a heating or cooling operation (2-pipe system) as well as a heating and cooling operation (4-pipe system).
In the mixing section of the unit the conditioned secondary air is mixed with the primary air and discharged horizontally (coanda effect) into the room via slots.
The unit comprises external casing, edge profiles and suspension lugs.
The end of the casing can be fitted with optional support angles which are supplied loose. Control components can be supplied loose.

Materials:
The casing, primary air duct and perforated plate induction grille are made of galvanised steel sheet, the induction bar grille, side frames and end frames are made of extruded aluminium profiles. The casing as standard has a galvanised surface – coil is untreated, optionally casing and coil can be dip coated in black (RAL 9005), visible surfaces of the induction grille completely powder-coated in pure white (RAL 9010) or optionally in another colour of the RAL colour scale.
The discharge nozzles are made of black plastic, the coil of copper pipes with formed aluminium fins. The flexible hose available as an accessory is made of special plastic with a stainless steel sheathing.

Order Code

These codes do not need to be completed for standard products.

DID300-G-2-A-MHR / 1800 x 1500 / KW / 207 / P1 / RAL 9016 / G1

Induction grille:
Bar (grille) G
Perforated plate LR
(round-hole sheet metal)

Coils:
Two-pipe 2
Four-pipe 4

Nozzle options A, B, C

For casing arrangements
(see page 4)

L_t* (mm) × L_N* (mm)
1200 x 1200 1500 1800
1500 x 1500 1800 2100
1800 x 1800 2100 2400
2100 x 2100 2400 2700
2400 x 2400 2700 3000
2700 x 2700 3000
3000 x 3000

Casing and coil:
0 Standard

Casing and coil:
G1 dip-coated according to RAL 9005

Casing:
G2 dip-coated according to RAL 9005

State colour

0 Standard finish
Entire visible surfaces powder-coated to RAL 9010 (GE 50%) [1]
P1 Powder-coated to RAL.... (GE 70%) [1]

Control components see Page 7!

0 [3] without condensation tray
KW with condensation tray

1) GE = Gloss level
2) For water connection Ø 12 mm!
3) Version without condensation tray with 3-way valve and with self-contained control not possible!

* L_t = Total length (diffuser face)
L_N = Nominal length

Note:
L_t dimensions of 1200 ... 3000 mm possible,
L_N dimensions only standard lengths.
L_t max. 7 mm shorter than L_N!

Accessories:
FS12-A / 500 (see table)
AW = Support angles

Accessories: Flexible hose (FS12)[2] (cf. page 7)

Possible connections		
both ends	combination	Length in mm
FS12-S	FS12-S/U	500, 750, 1000
FS12-U	FS12-S/A	
FS12-A	FS12-U/A	

Order example without control components

Manufacture: TROX
Type: DID300-G-2-K-MHR/1800x1500/KW/P1/RAL9016/G1

Order Example with control components

Manufacture: TROX
Type: DID300-LR-2-A-MHR/1800x1500/KW/207/P1/RAL9016/G1

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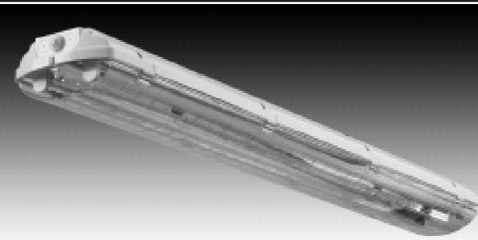
Appendix L: Cut Sheets for Lamp Selection

HOLOPHANE® LEADER IN LIGHTING SOLUTIONS

CTL

Controlume



APPLICATIONS

The Controlume Series is ideal for harsh or wet environments where materials such as steel and aluminum may deteriorate. Applications requiring emergency power, impact resistance, battery backup, instant-on starting or hot-restrike such as storage areas, water treatment plants, industrial spaces, parking garages, waste-water treatment facilities or locker rooms will find this luminaire to be the fixture of choice.

FEATURES

Self extinguishing, lightweight and durable polycarbonate housing construction with a poured silicon gasket that is "hot-bonded" to the housing during manufacturing provides excellent moisture and dust penetration resistance.

Innovative C.L.E. (complete light emission) UV stabilized clear diffuser made of 100% polycarbonate material with clean architectural styling incorporates excellent impact resistance.

Dual concave parabolic reflector with a vacuum metalized finish.

Available in 2' and 4' nominal lengths in T8, T5 or T5HO lamp sources.

Flush fitting, integral and captive non-corrosive fiberglass reinforced clips are not prone to rust.

The Controlume Series is configurable with multiple modes of operation: AC only mode, Emergency only mode or AC and Emergency mode.

UL listed in the U.S. and Canada for wet locations in environments up to 60°C. IP66 rated.

MODELS AVAILABLE

Fixture Schedule

Fixture ID#

CTL	4	HT	0	254	12	
Fixture Series	Nominal Length	Operation	Emergency Lamp Qty.	Lamp Configuration	Voltage	Options
CTL	2 - 2' 4 - 4'	HT - AC Operation Only SE - Emergency Operation Only SA - AC & Emergency Operation	0 - 2-Lamp AC 1 - 1 Lamp Emergency 2 - 2 Lamp Emergency	217 - 2 Lamp, T8, 17W 214 - 2 Lamp, T5, 14W 224 - 2 Lamp, T5HO, 24W 232 - 2 Lamp, T8, 32W 228 - 2 Lamp, T5, 28W 254 - 2 Lamp, T5HO, 54W	12 - 120V C/UL/US 27 - 277V C/UL/US 34 - 347V C/UL/US U - Dual Voltage 120V & 277V	F1 - Single Fusing

Not all photometric configurations are available with every lamp configuration
Not all ballast types and quantities are available with every lamp configuration
Contact your sales representative for more information.

HL-2202 7/06

SPECIFICATIONS

Housing: Self extinguishing, lightweight and durable polycarbonate construction with a poured silicon gasket that is "hot-bonded" to the housing during manufacturing. Anti-aging, expanded polyurethane gasketing and fiberglass reinforced closure clips. 1/2" conduit knockouts are provided on each end.

Optics: Computer designed, dual concave high efficiency reflector with a vacuum metalized finish.

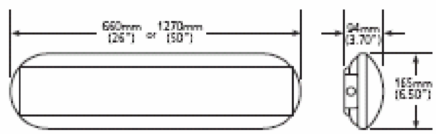
Lamps: (2) T8, (2) T5 or (2) T5HO lamps are secured with rotary locking lampholders.

Electrical: UL/CUL labeled for wet location. IP66 rated. Fixture is suitable for ambient temperatures up to 60°C. Fully wired with universal voltage, 60Hz AC, thermally protected, Class P, high power factor, non-PCB, Sound rated A, programmed start, electronic T5 or T5HO ballast or electronic universal voltage T8 ballasts. Emergency ballasts and protective fusing are optional.

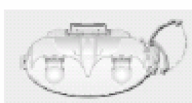
Mounting: The Controlume Series is designed to be ceiling mounted, wall mounted, rail mounted, pendant or chain mounted. Suitable for wet locations.

Finish: The Controlume Series is available with off-white polycarbonate housing and clear polycarbonate lens.

CROSS SECTIONS

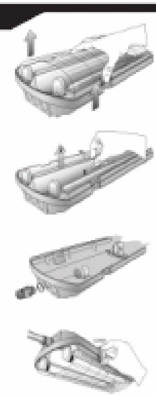


FIXTURE DETAIL

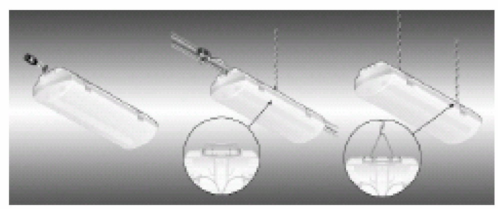


Fiberglass reinforced clasps fit flush to the housing.

Service bracket allows trouble-free installation/service.

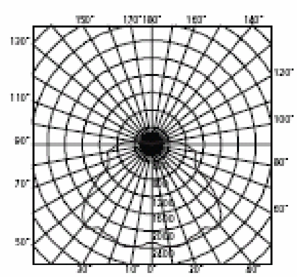


The Controlume is easy to install and maintain. The three-piece design (lens, reflector, housing) fit together to form a weather-proof seal and durable luminaire. The no tool design allows for the industry's easiest installation. (See drawing at left.)
Simply remove the high-output lens by opening the flush polycarbonate clips (2ft = 4 clips / 4ft = 8 clips). Remove the high-efficiency reflector from the housing by pinching the two (2) pressure clips together and lifting the reflector away from the housing. (Note: the reflector can be hung from the housing using the incorporated service bracket.) Wiring of the electronic ballast can now be accomplished. 1/2" conduit knockouts are provided on each end of the housing. Other housing entry points can be used for mounting variations. Finally, snap the reflector back in place, secure the high-output lens and lock down the closure clips.



Surface Mount Rail Mount Chain Mount

PHOTOMETRY



CTL4HT0254
SC Across: 1.6, SC Along: 1.3

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