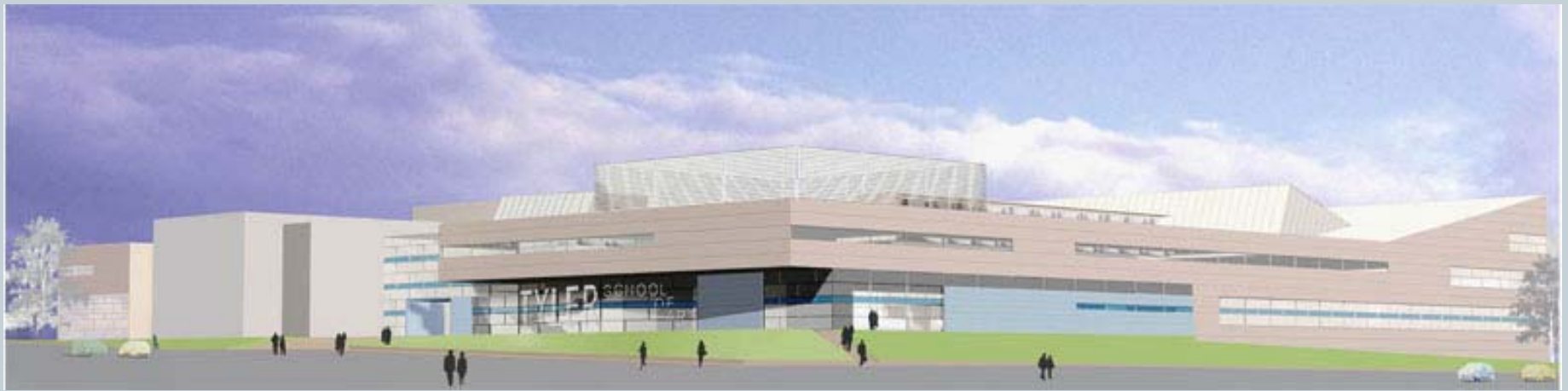


Temple University Tyler School of Art



DOUG BOSWELL
MECHANICAL OPTION
APRIL 16, 2008



Presentation Outline



- **Project Overview**
- **Existing Mechanical Systems**
- **Proposed Redesign**
- **Electrical Considerations**
- **Mechanical Construction Cost**
- **Life Cycle Cost Analysis**
- **Conclusions**



Project Overview



- **Building Owner: Temple University**
- **Building Location: Philadelphia, PA**
 - Campus moving from Elkins Park, PA to Main Campus
- **Art Education**
 - Building divided by Departments
- **234,000 SF**
- **\$75 Million**
- **Construction Complete January 2009**



Tyler School of Art

o Designed by Carlos Jimenez

o School Features
160,000 SF of Teaching Space

o Building Includes
Studio, Galleries,
Administration, and
Workshops

o Departments Include
Painting, Metals,
Printmaking, Sculpture,
etc.

o 40% More SF than
Elkins Park Campus



Existing Mechanical Conditions



- **Campus Chiller/Boiler Plant**
 - 40,000 lbs/hr of HPS supplied at 240°F
- **HPS Converted to LPS**
 - LPS used for preheat coils, AHUs, and heat exchangers
- **LPS Converted to Hot Water Heat through Heat Exchanger**
 - Hot Water System serves terminal heating equipment
 - ✦ Hot Water Supply: 180°F
 - ✦ Hot Water Return: 160°F

Existing Mechanical Conditions



- Served by 3 RTUs & 4 basement AHUs
 - 2 RTUs & 2 AHUs are VAV Reheat
 - 1 RTU & 2 AHUs are CAV Reheat
 - Units Range 35,000-62,000 CFM
 - CAVR units are 100% OA

Space	HVAC System
Administration & Office	Variable Air Volume Reheat (VAVR)
Classroom Spaces	Variable Air Volume Reheat (VAVR)
Conference & Presentation	Variable Air Volume Reheat (VAVR)
Workshop & Studio Areas	Constant Air Volume Reheat (CAVR)



VAV/CAV Advantages



- **Low First Cost**
- **Low Maintenance**
- **Simple & Inexpensive Controls**
- **Flexibility**



VAV/CAV Disadvantages

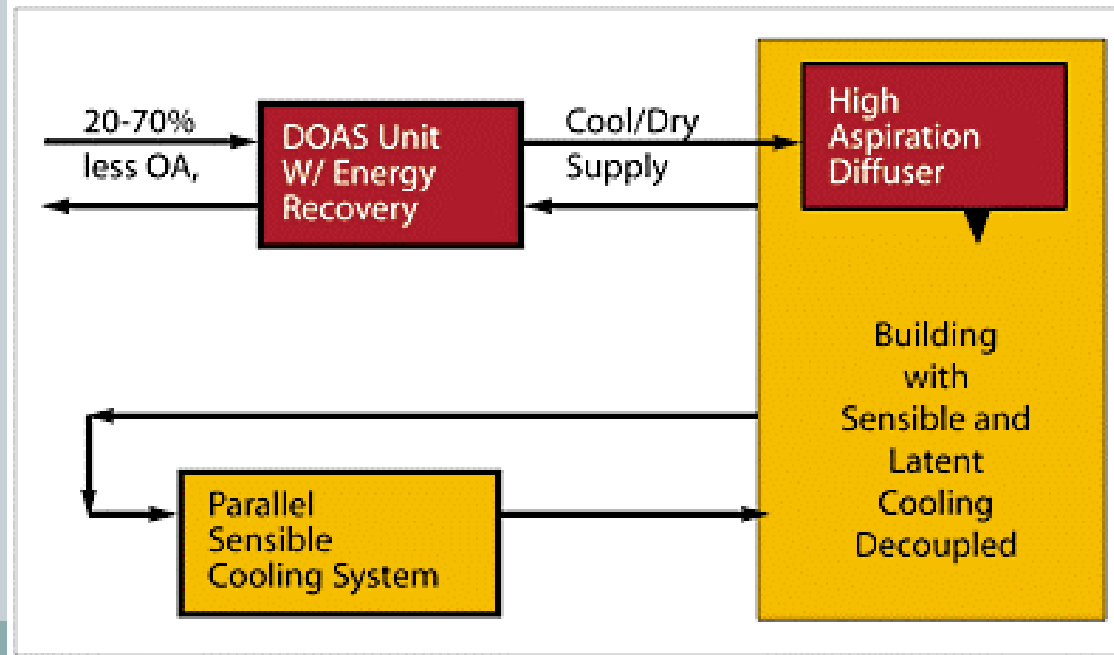


- **High Energy Consumption**
- **Inadequate Airflow**
- **Single Box Serves Multiple Spaces**
- **Large Ductwork**

Redesign Summary



- Replace VAV/CAV units with Dedicated Outdoor Air (DOAS) Units
- Parallel Sensible System: Chilled Beams
- Energy Consumption Improvement



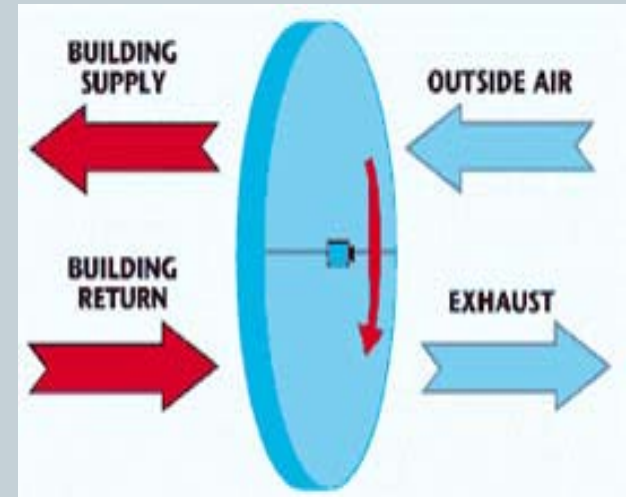
Dedicated Outdoor Air System (DOAS)



- **Separates Latent from Sensible Loads**
- **Energy Savings with Decreased Fan and Chilled Energy**
- **Paired with Parallel Sensible System**
- **Improved Indoor Air Quality and Thermal Comfort**

Energy Recovery

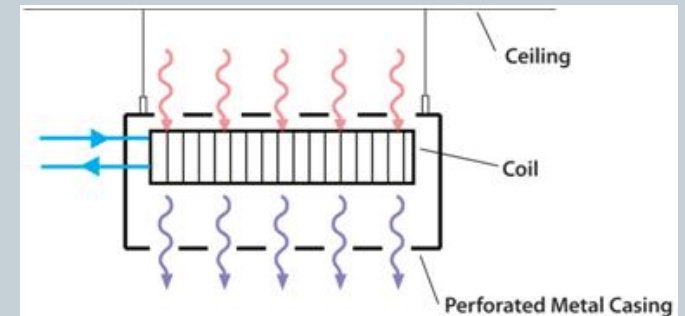
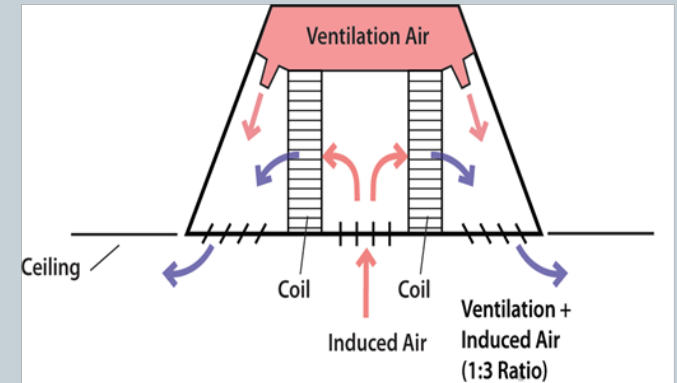
- Included as Part of DOAS
- Advantages
 - Reduce Cooling/Heating Loads
 - Downsize Equipment/Ductwork
- Disadvantages
 - Increased First Cost
 - Fan Energy
 - Required Air Filtration



Chilled Beams



- Active Beams Mix Supply Air with Existing Air
- Passive Beams Use Natural Convection
 - Warm Air Rises While Cool Air Falls



Chilled Beams



- **Advantages**

- Pump Energy instead of Fan Energy
- Mechanical System and Duct Reductions
- Higher Air Temperature Because Direct Cooling

- **Disadvantages**

- Cost
- Condensation
- High Sensible Loads
- U.S. Availability

DOAS Ventilation Air Summary



	DOAS Supply Air	Square Feet Served	CFM/FT ²
AHU-1/2	25,336	39,786	0.637
AHU-3/4	31,284	67,333	0.465
RTU-1	19,727	30,757	0.641
RTU-2	8,127	21,749	0.374
RTU-3	8,423	20,410	0.413
Total CFM	92,897		

	Total CFM	Total % Reduction
Original Design	352,000	73
Redesign	92,897	

DOAS System Layout

	Total CFM	Areas Served
DOAS-1	22,213	RTU-2, RTU-3, AHU-3/4
DOAS-2	22,733	AHU-3/4
DOAS-3	25,336	AHU-1/2
DOAS-4	22,615	RTU-1, AHU-3/4



Chilled Beams Required

- Halton, Inc. Chilled Beams Used
- Heating/Cooling
- Wide Occupancy Ranges
- Handle High Sensible Loads

Floor	MBH	Chilled Beams Required
1st	930.2	233
2nd	1344.4	336
3rd	418.8	105
Basement	310.3	78
Total	3003.7	751



Halton CCE Active Chilled Beam

Annual Existing Energy Cost



- Annual Operating Cost of \$500,428.00

TYLER SCHOOL ORIGINAL DESIGN		Annual Revised Cost	Total Cost (%)
	Air System Fans	\$135,442.00	27.1
	Cooling	\$76,924.00	15.4
	Heating	\$50,372.00	10.1
	Pumps	\$26,110.00	5.2
	Cooling Tower Fans	\$32,436.00	6.5
	<i>HVAC Sub-Total</i>	<i>\$321,285.00</i>	<i>64.2</i>
	Lights	\$107,486.00	21.5
	Electric Equipment	\$71,657.00	14.3
	<i>Non-HVAC Total</i>	<i>\$179,143.00</i>	<i>35.8</i>
	TOTAL	\$500,428.00	100

Annual Existing Energy Cost

DOAS		Annual Revised Cost	Total Cost (%)
	Air System Fans	\$42,329.00	24
	Cooling	\$33,614.00	19.1
	Heating	\$69,548.00	39.5
	Pumps	\$13,493.00	7.7
	Cooling Tower Fans	\$17,259.00	9.8
	TOTAL	\$176,243.00	100

CHILLED BEAMS		Annual Revised Cost	Total Cost (%)
	Air System Fans	\$19,591.00	12.2
	Cooling	\$23,469.00	14.7
	Heating	\$18,153.00	11.3
	Pumps	\$13,269.00	8.3
	Cooling Tower Fans	\$12,408.00	7.7
	<i>HVAC Sub-Total</i>	<i>\$86,889.00</i>	<i>54.3</i>
	Lights	\$43,941.00	27.4
	Electric Equipment	\$29,294.00	18.3
	<i>Non-HVAC</i>	<i>\$73,235.00</i>	<i>45.7</i>
	TOTAL	\$160,124.00	100

ANNUAL ENERGY COST	
Existing	\$500,428.00
Redesigned	\$336,367.00

**Annual Energy Cost Savings of
\$164,061.00**

Annual Energy Consumption

Existing System

ORIGINAL		Annual Energy Consumption	\$/yr
	<i>HVAC</i>		
	Electric (kWh)	3,764,578	\$271,240.00
	Natural Gas (Therm)	38,006	\$50,044.00
	<i>Non HVAC</i>		
	Electric (kWh)	2,485,585	\$179,144.00
	TOTAL ELECTRIC	6,250,163	\$500,428.00

Redesigned System

DOAS		Annual Energy Consumption	\$/yr
	Electric (kWh)	2,213,175	\$161,739.00
	Natural Gas (Therm)	47,034	\$14,504.00
CHILLED BEAMS	<i>HVAC</i>		
	Electric (kWh)	941,153	\$68,854.00
	Natural Gas (Therm)	13,270	\$18,035.00
	<i>Non HVAC</i>		
	Electric (kWh)	997,188	\$73,235.00
	TOTAL ELECTRIC	1,938,341	\$142,089.00
	TOTAL COST		\$336,367.00

Annual Energy Consumption



- **Electric Reduction of Approximately 33%**

ANNUAL ENERGY CONSUMPTION		
	Existing System	Redesign
Electric (kWh)	6,250,163	4,151,516
Natural Gas (Therm)	38,006	60,304

Electrical Considerations



	PROTECTIVE DEVICE			FEEDER					DESCRIPTI ON
	CB FRAME (AMPS)	NO. POL ES	TRIP (AM PS)	NO. SETS	WIRE QTY./SET	CONDUCTOR SIZE (AWG OR KCMIL)	GROUND SIZE PER SET	CONDUIT SIZE PER SET	SERVICE
EQUIPMENT REMOVED	225	3	200	1	3	3/0	6	2	AHU-1
	225	3	200	1	3	3/0	6	2	AHU-2
	250	3	250	1	3	250	4	2 1/2	AHU-3
	250	3	250	1	3	250	4	2 1/2	AHU-4
	225	3	200	1	4	3/0	6	2	RTU-1
	225	3	125	1	4	1	6	1 1/2	RTU-1
	225	3	200	1	3	3/0	6	2	RTU-2
	100	3	100	1	3	1	8	1 1/2	RTU-2
	225	3	125	1	3	1	6	1 1/2	RTU-3
	100	3	100	1	3	1	8	1 1/2	RTU-3
EQUIPMENT ADDED	50	3	45	1	3	10	8	1/2	DOAS-1
	40	3	35	1	3	10	8	1/2	DOAS-2
	50	3	45	1	3	10	8	1/2	DOAS-2
	40	3	35	1	3	10	8	1/2	DOAS-2
	50	3	45	1	3	10	8	1/2	DOAS-3
	40	3	35	1	3	10	8	1/2	DOAS-3
	50	3	45	1	3	10	8	1/2	DOAS-4
	40	3	35	1	3	10	8	1/2	DOAS-4

EXISTING SYSTEM COST		
CONDUCTOR	\$1,792.95	
GROUND	\$339.73	
CONDUIT	\$4,610.40	
TOTAL COST		\$6,743.08
DOAS REDESIGN		
CONDUCTOR	\$228.16	
GROUND	\$200.88	
CONDUIT	\$10.76	
TOTAL COST		\$439.80
Potential Electrical Savings		\$6,303.28

Electrical Considerations



Voltage Drop							
SERVICE	CONDUCTOR SIZE (AWG OR KCMIL)	FT WIRE	Amp s	Voltage Drop Per 1000 Amp-Ft	VD L to L	% VD	Less Than 2%
DOAS-1	10	52	50	1.103	4.96	1.03	Yes
DOAS-1	10	52	40	1.103	3.97	0.83	Yes
DOAS-2	10	56	50	1.103	5.34	1.11	Yes
DOAS-2	10	56	40	1.103	4.27	0.89	Yes
DOAS-3	10	40	50	1.103	3.82	0.80	Yes
DOAS-3	10	40	40	1.103	3.05	0.64	Yes
DOAS-4	10	100	50	1.103	9.54	1.99	Yes
DOAS-4	10	100	40	1.103	7.63	1.59	Yes

NEC Suggests VD of 3% for Branch Circuits

Initial Cost Comparison



	Existing System	DOAS Redesign
CAV AHUs (2)	\$136,000.00	
VAV AHUs (2)	\$42,100.00	
CAV RTU	\$39,300.00	
VAV RTU (2)	\$98,800.00	
VAVR Boxes	\$100,775.00	
Diffusers	\$65,856.00	
Duct	\$112,745.17	\$67,782.18
DOAS (4)		\$120,000.00
Chilled Beams		\$1,502,000.00
Electrical Totals	\$6,743.08	\$439.80
Initial Total Cost	\$602,319.25	\$1,690,221.98

First Cost Comparison	\$1,087,903
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20 Year Life Cycle Cost



- Assume $i = 0.06$

	Existing System	DOAS Redesign
Initial Cost	\$602,319.00	\$1,690,221.00
Years	Annual Operating Cost	Annual Operating Cost
20	\$500,428.00	\$336,367.00
Net Present Worth	\$5,739,869.74	3,858,095.85
Total Cost	\$6,342,188.74	\$5,548,316.85

Total Potential 20 Year Savings	\$793,871.89
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- Payback = 8.7 years

Conclusion



- **DOAS w/ Chilled Beams is Beneficial and Recommended for the Tyler School of Art**
- **Considerations**
 - DOAS Design Software
 - Early Design Coordination for Chilled Beams
 - Contractor Familiarity

Questions?

