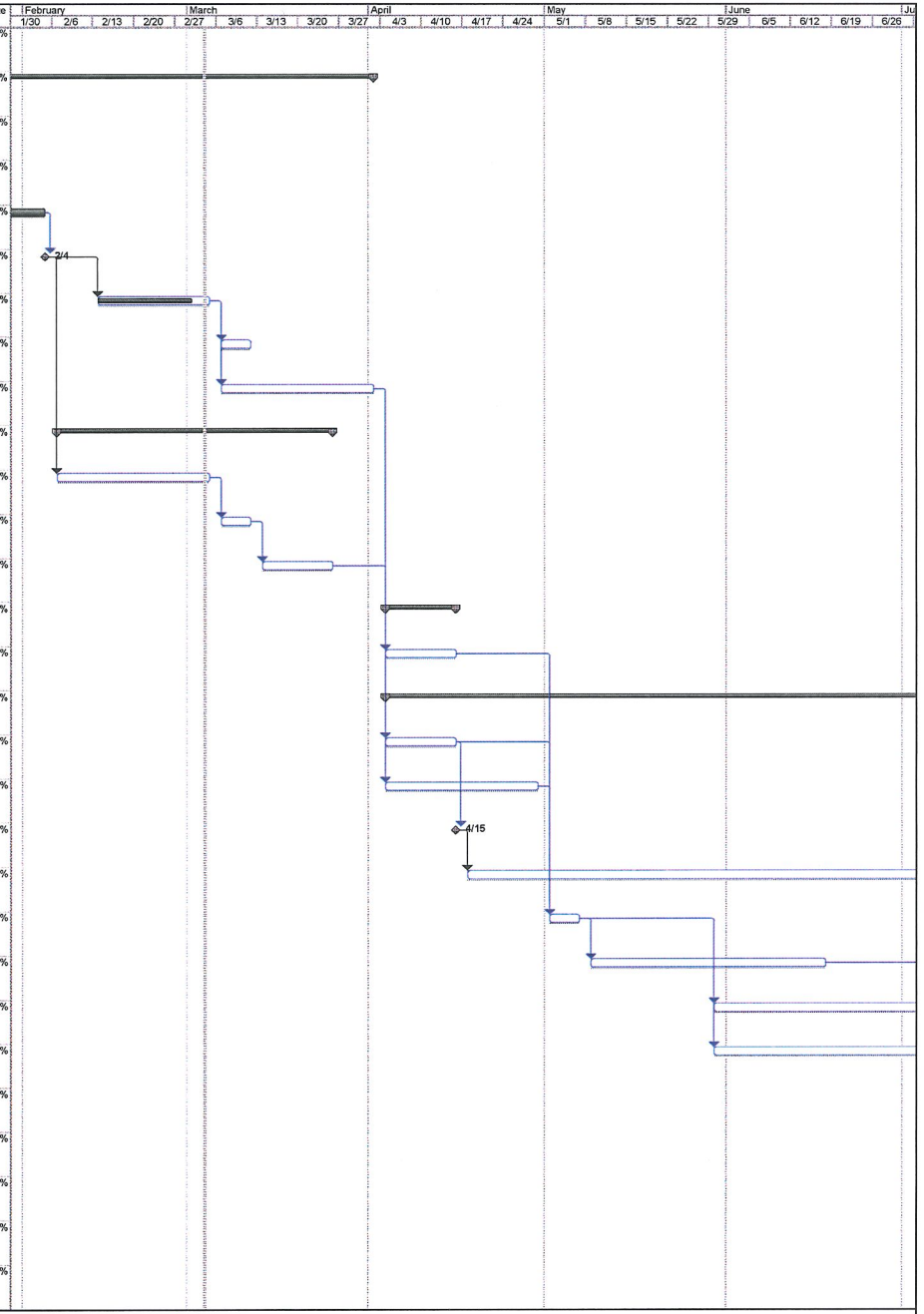
Manalapan Township, Main Building & Police Headquarters Energy Savings Report

Table of Contents

- **Project Schedule**
- **Energy Reduction Plan (P4P)**
- **Energy Savings Plan (ESIP) To follow**
- **Financial Evaluator**

Project Schedule

ID	Task Name	Duration	Start	Finish	Predecessors	% Complete
1	Award Contract	0 days	Fri 1/7/11	Fri 1/7/11		100%
2	**Project Development**	61 days	Fri 1/7/11	Fri 4/1/11	1	50%
3	Site Survey	5 days	Fri 1/7/11	Thu 1/13/11		100%
4	Evaluate & Select ECM's	5 days	Fri 1/14/11	Thu 1/20/11	3	100%
5	Develop Project Magnitude Report	6 days	Fri 1/28/11	Fri 2/4/11	4	100%
6	Manalapan Twp Approval	0 days	Fri 2/4/11	Fri 2/4/11	5	100%
7	Complete ESP/ERP	15 days	Mon 2/14/11	Fri 3/4/11	6	80%
8	Manalapan Twp Approval	5 days	Mon 3/7/11	Fri 3/11/11	7	0%
9	State approval	20 days	Mon 3/7/11	Fri 4/1/11	7	0%
10	**Engineering and Design**	**35 days**	**Mon 2/7/11**	**Fri 3/25/11**		0%
11	Design Energy Conservation Measures	20 days	Mon 2/7/11	Fri 3/4/11	6	0%
12	Manalapan Twp Review	5 days	Mon 3/7/11	Fri 3/11/11	11	0%
13	Complete Bid Documents	10 days	Mon 3/14/11	Fri 3/25/11	12	0%
14	**Financing**	**10 days**	**Mon 4/4/11**	**Fri 4/15/11**		0%
15	Bid out financing	10 days	Mon 4/4/11	Fri 4/15/11	9	0%
16	**Construction**	**70 days**	**Mon 4/4/11**	**Fri 7/8/11**		0%
17	Bid Chiller Pre-purchase	10 days	Mon 4/4/11	Fri 4/15/11	9	0%
18	Bid Construction Contracts	20 days	Mon 4/4/11	Fri 4/29/11	9,13	0%
19	Award Chiller Contract	0 days	Fri 4/15/11	Fri 4/15/11	17	0%
20	Deliver Chiller	60 days	Mon 4/18/11	Fri 7/8/11	19	0%
21	Award Installation Contracts	5 days	Mon 5/2/11	Fri 5/6/11	15,17,18	0%
22	ECM Lighting Improvements	30 days	Mon 5/9/11	Fri 6/17/11	21	0%
23	ECM HVAC Improvements	30 days	Mon 5/30/11	Fri 7/8/11	21,20FF	0%
24	ECM Building Controls	30 days	Mon 5/30/11	Fri 7/8/11	21,20FF	0%
25	Construction Completion	0 days	Fri 7/8/11	Fri 7/8/11	22,23,24	0%
26	Commissioning	5 days	Mon 7/11/11	Fri 7/15/11		0%
27	Training	5 days	Mon 7/11/11	Fri 7/15/11	25	0%
28	Measurement and Verification	5 days	Mon 7/11/11	Fri 7/15/11	25	0%
29	Turn Over	0 days	Fri 7/15/11	Fri 7/15/11	27,28	0%



Project: Manalapan
Date: Fri 3/4/11

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

Energy Reduction Plan (P4P)

New Jersey Office of Clean Energy

PAY FOR PERFORMANCE PROGRAM
ENERGY REDUCTION PLAN

Existing Buildings Component



Manalapan Township, Main Building / Police Headquarters
120, Route 522, Manalapan, NJ

Owner: Township of Manalapan
Phone: (732) 446-8342
Application Number: 11876

Audit Date: February, 1, 2011 to March 4, 2011

Report Prepared by: Tozour Energy Systems
Report Date: March 4, 2011

Revision # 0

Table of Contents

EXECUTIVE SUMMARY ..... **IV**

SECTION I – PROJECT DESCRIPTION **6**

Background Information 6
Building Occupancy 6
Energy Suppliers, Metering, and Electrical Systems 7
Envelope 7
Lighting ..... **Error! Bookmark not defined.**
Mechanical Systems 10
Operation and Maintenance 14
Process Equipment and Systems 14

SECTION II – FACILITY SIMULATION **15**

Major Assumptions Used to Establish the Baseline 15
Baseline Facility Variables 15
Calibration 15

SECTION III – RECOMMENDED MEASURES **16**

Measures Recommended for the Project 19
Energy Efficiency Options Examined But Not Recommended 18

SECTION IV – FINANCING PLAN **22**

SECTION V – IMPLEMENTATION SCHEDULE **23**

SECTION VI – METERING PLAN **24**

List of Tables

Table 1. Summary of P4P Program Metrics iv
Table 2. Summary of Program Incentives v
Table 3. Area Identification 6
Table 4. Occupancy Schedules 6
Table 5. Utility Summary 7
Table 6. Envelope Summary 7
Table 7a. Lighting Detail 8
Table 8. Motors 11
Table 9. HVAC Schedule 12
Table 10. Boiler and Domestic Hot Water 12
Table 11. Chillers and Condensers 13
Table 12. Model Calibration Statistics 15
Table 13. Recommended Measures - Description 17
Table 14. Recommended Measures - Cost and Energy Savings 18
Table 15. Financing Plan 22
Table 16. Implementation Schedule 23

List of Appendices

Appendix A: EPA *Portfolio Manager* Summary
Appendix B: Simulation Reports – (separate attachment)
Appendix C: Modeling Assumptions
Appendix D: Supporting Calculations
Appendix E: Pre-Retrofit Metering Results
Appendix F: Combined Heat and Power Application

EXECUTIVE SUMMARY

In connection with New Jersey's Clean Energy Pay for Performance Program, this Energy Reduction Plan (ERP) presents the findings of a comprehensive assessment which evaluated potential energy saving measures for Manalapan Main & Police building in Englishtown, NJ. This ERP details specific steps to be taken by the project owner to achieve or exceed a minimum target source energy savings of 15%. Included in this ERP are energy and cost analyses used in determining the list of recommended energy saving measures. This ERP is prepared in accordance with version 2.0 of the Pay for Performance Program Guidelines and NJ Clean Energy Program Protocols to Measure Resource Savings.

Table 1 illustrates a summary of the project in terms of energy consumption, estimated savings and EPA Portfolio Manager output. Table 2 includes a summary of the Program incentives.

Table 1. Summary of P4P Program Metrics

	Annual Consumption*	Projected Savings	% Savings	Actual Savings
Electricity (kBtu)	3,350,584	840,935	25%	0
Natural Gas (kBtu)	1,484,700	212,000	14%	0
Source Energy Use Intensity (kBtu/ft^2)	425.0	101.0		0.0
Source Energy Use Reduction			24%	0%

1) Is this project applying for ARRA incentives for Non-Investor Owned Utility? 2) **Or** is this project performing a fuel switch?	

Total Investment ($)	$322,486
Annual Savings ($)	$43,144
Internal Rate of Return (IRR)	11%
Simple Payback (yrs)	7.5
Initial Benchmark Score	10

Table 2. Summary of Program Incentives

Project Summary	
Total Project Area (sq. ft.)	30,019
Annual Energy Cost ($)	$178,926
Reduction from Baseline: Proposed (%)	24%
Reduction from Baseline: Actual (%)	0%
Total Project Cost ($)	$322,486
Incentives	
Incentive #1	$5,000
Incentive #2	$29,761
Incentive #3 (Projected)	$29,761
Incentive #3	$0
CHP Advanced Measure Incentives	**kW**
Level 1	0
Level 2	0
Cooling Application?	No
Level 3	0
CHP Advanced Measure Incentive	$0

This plan has been developed by Brian Peifer at Tozour Energy Systems. All questions should be addressed to Brian Peifer at (484) 678-8901 or by email at bpeifer@tozourenergy.com

SECTION I – PROJECT DESCRIPTION

This ERP addresses the following facility: Manalapan main township building & police headquarters assessment>. On February 1, 20011 through March 4, 2011 Brian Peifer from Tozour Energy Systems visited the project site and conducted a detailed energy assessment of the property.

The project was evaluated using the US EPA's *Portfolio Manager* benchmarking tool to examine current energy consumption relative to similar facilities prior to implementation of recommended measures. The facility is included under the Office in *Portfolio Manger* and has an initial Performance Rating Benchmark of **10** *Portfolio Manager* results can be found in Appendix A.

Background Information

Table 3. Area Identification

	Area Name/ID	Building	Description/Use	Sq. Ft.
1	First Floor	Main	Office space	10,375
2	Second Floor	Main	Offic space & main lobby	10,375
3	Second Floor	Police	Manalapan Police department	9,270
4	First Floor	New Area	Future Police area, was unconditioned storage during baseline period	0
			Total	**30,019**

Building Occupancy

Table 4. Occupancy Schedules

Schedule Name:	**Main**		Applicable from:		Jan	to	Dec
	Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
Hours Open	9	9	9	9	9	5	
Number of Occupants When Open	75	75	75	75	75	25	

Schedule Name:	**Police**		Applicable from:		Jan	to	Dec
	Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
Hours Open	24	24	24	24	24	24	24
Number of Occupants When Open	25	25	25	25	25	15	10

Energy Suppliers, Metering, and Electrical Systems

Electricity supplied by JCP&L, account # 20 00 00 0561 7 2, meter # G28642551, rate is general service secondary 3 phase. Natural gas supplied by New Jersey Natural Gas, account # 10-3448-4580-13, meter # 00267354. Monthly energy use tables can be found in Appendix A.

Table 5. Utility Summary

	Electricity (kWh)	Natural Gas (MMBtu)	Steam (MMBtu)	Fuel Oil (MMBtu)	<Other> (MMBtu)
Total Annual Use	982,000	1,485	0	0	0
Total Cost	$159,631	$19,295			
Average Unit Cost	$0.163	$13.00	$0.00	$0.00	$0.00

Analysis Period	Start:	1/1/2010
	End:	12/31/2010

Envelope

Table 6. Envelope Summary

Construction Style	2 story building Standard block & brick
Windows	Single pane with aluminum frames
Doors	Lobby door s & exits - standard glass doors
Roof	Standard concrete slab roof

Table 7a. Lighting Detail

Existing Lighting Data - Main Building						New Lighting Data - Main Building				
Location	Fixture Type	# Of Fixtures	Lamps Per Fixture	Watts Per Fixture	Total Watts	Fixture Type	Occupancy Sensor Adjustment Factor	Watts Per Fixture	Total Watts	Total Watts Adjusted
Stair No. 2	100W Mercury Vapor	9	1	125	1125.00	Compact Fluorescent	1.00	57	513	513
Conference Room	2x4 Electronic Fluorescent	3	3	100	300.00	Replace Ballast & Lamps	1.00	71	213	213
Conference Room	100W Mercury Vapor	2	1	125	250.00	Compact Fluorescent	1.00	57	114	114
Central Files	2x4 Electronic Fluorescent	5	3	100	500.00	Replace Ballast & Lamps	0.75	71	355	266.25
Corridor	100W Mercury Vapor	12	1	125	1500.00	Compact Fluorescent	1.00	57	684	684
Corridor	2x2 Electronic Fluorescent	8	3	70	560.00	Replace Ballast & Lamps	1.00	42	336	336
Health	2x4 Electronic Fluorescent	1	3	100	100.00	Replace Ballast & Lamps	1.00	71	71	71
Clerical/Files	2x4 Electronic Fluorescent	4	3	100	400.00	Replace Ballast & Lamps	1.00	71	284	284
Clerical/Files	2x2 Electronic Fluorescent	2	3	70	140.00	Replace Ballast & Lamps	1.00	42	84	84
Inspector	2x4 Electronic Fluorescent	1	3	100	100.00	Replace Ballast & Lamps	0.50	71	71	35.5
Inspector	2x4 Electronic Fluorescent	1	3	100	100.00	Replace Ballast & Lamps	0.50	71	71	35.5
Health Office	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.75	71	142	106.5
Storage	2x4 Electronic Fluorescent	2	2	70	140.00	Replace Ballast & Lamps	0.25	48	96	24
Purchasing Agent	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.75	71	142	106.5
Women Restroom	Strip Fluorescent	2	2	70	140.00	Replace Ballast & Lamps	1.00	48	96	96
Men Restroom	Strip Fluorescent	2	2	70	140.00	Replace Ballast & Lamps	1.00	48	96	96
Records	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.50	71	142	71
Deputy Clerk	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.50	71	142	71
Clerical	2x4 Electronic Fluorescent	4	3	100	400.00	Replace Ballast & Lamps	1.00	71	284	284
Clerical	100W Mercury Vapor	2	1	125	250.00	Compact Fluorescent	1.00	57	114	114
Ass't Admin	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.50	71	142	71
Admin	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.50	71	142	71
Cler/Admin	2x4 Electronic Fluorescent	5	3	100	500.00	Replace Ballast & Lamps	1.00	71	355	355
Cler/Admin	100W Mercury Vapor	1	1	125	125.00	Compact Fluorescent	1.00	57	57	57
Mayor	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.75	71	142	106.5
Finance/Tax Collector	2x4 Electronic Fluorescent	10	3	100	1000.00	Replace Ballast & Lamps	1.00	71	710	710
Finance/Tax Collector	100W Mercury Vapor	4	1	125	500.00	Compact Fluorescent	1.00	57	228	228
Tax Collector Office	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.50	71	142	71
Treasurer	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.50	71	142	71
Vault	1x4 Electronic Fluorescent	1	2	70	70.00	Replace Ballast & Lamps	0.25	48	48	12
Tax Assesor	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.50	71	142	71
Clerical Area	2x4 Electronic Fluorescent	6	3	100	600.00	Replace Ballast & Lamps	1.00	71	426	426
Clerical Area	2x2 Electronic Fluorescent	1	3	70	70.00	Replace Ballast & Lamps	1.00	42	42	42
Meeting Room	2x4 Electronic Fluorescent	3	3	100	300.00	Replace Ballast & Lamps	1.00	71	213	213
Micro/Copy	2x4 Electronic Fluorescent	3	3	100	300.00	Replace Ballast & Lamps	0.50	71	213	106.5
Caucus Room	2x4 Electronic Fluorescent	6	3	100	600.00	Replace Ballast & Lamps	1.00	71	426	426
Court Room	2x4 Electronic Fluorescent	4	3	100	400.00	Replace Ballast & Lamps	1.00	71	284	284
Court Room	100W Mercury Vapor	20	1	125	2500.00	Compact Fluorescent	1.00	57	1140	1140
Court Room	Indirect Fluorescent	15	2	120	1800.00	Replace Ballast & Lamps	1.00	107	1605	1605
Magistr	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.75	71	142	106.5
Attorney	2x4 Electronic Fluorescent	1	3	100	100.00	Replace Ballast & Lamps	0.75	71	71	53.25
Municipal Court	2x4 Electronic Fluorescent	6	3	100	600.00	Replace Ballast & Lamps	1.00	71	426	426
Files	2x2 Electronic Fluorescent	2	2	45	90.00	Replace Ballast & Lamps	0.25	33	66	16.5

Court Clerk	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.75	71	142	106.5
Main Lobby	100W Mercury Vapor	31	1	125	3875.00	Compact Fluorescent	1.00	57	1767	1767
Main Lobby	Undercounter Fluorescent	3	2	70	210.00	Undercounter Fluorescent	1.00	70	210	210
Main Lobby	2x2 Electronic Fluorescent	4	3	70	280.00	Replace Ballast & Lamps	1.00	42	168	168
Main Lobby	Incandescent	9	1	150	1350.00	Compact Fluorescent	1.00	26	234	234
Stair No. 1	100W Mercury Vapor	9	1	125	1125.00	Compact Fluorescent	1.00	57	513	513
Stair No. 2	100W Mercury Vapor	2	1	125	250.00	Compact Fluorescent	1.00	57	114	114
Shower	Incandescent	1	1	150	150.00	Compact Fluorescent	0.25	26	26	6.5
Shower	1x4 Electronic Fluorescent	1	2	70	70.00	Replace Ballast & Lamps	0.25	48	48	12
Mud Room	2x4 Electronic Fluorescent	1	2	70	70.00	Replace Ballast & Lamps	0.25	48	48	12
Corridor	2x2 Electronic Fluorescent	11	3	70	770.00	Replace Ballast & Lamps	1.00	42	462	462
Corridor	100W Mercury Vapor	17	1	125	2125.00	Compact Fluorescent	1.00	57	969	969
Welfare	2x4 Electronic Fluorescent	4	3	100	400.00	Replace Ballast & Lamps	0.75	71	284	213
Director	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.75	71	142	106.5
Men Restroom	Strip Fluorescent	2	2	70	140.00	Replace Ballast & Lamps	0.25	48	96	24
Women Restroom	Strip Fluorescent	2	2	70	140.00	Replace Ballast & Lamps	0.25	48	96	24
Conference Room	2x4 Electronic Fluorescent	3	3	100	300.00	Replace Ballast & Lamps	1.00	71	213	213
Planning/Clerical	2x4 Electronic Fluorescent	4	3	100	400.00	Replace Ballast & Lamps	0.75	71	284	213
Storage	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.25	71	142	35.5
Office	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.75	71	142	106.5
Storage	2x4 Electronic Fluorescent	2	2	70	140.00	Replace Ballast & Lamps	0.25	48	96	24
Construction	2x4 Electronic Fluorescent	12	2	48	576.00	Leave Existing Fixtures	1.00	48	576	576
Director	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.75	71	142	106.5
Enforcement	2x4 Electronic Fluorescent	2	3	100	200.00	Replace Ballast & Lamps	0.75	71	142	106.5
Storage	2x4 Electronic Fluorescent	1	2	70	70.00	Replace Ballast & Lamps	0.25	48	48	12
Office	2x4 Electronic Fluorescent	1	3	100	100.00	Replace Ballast & Lamps	0.75	71	71	53.25
Office	2x4 Electronic Fluorescent	1	3	100	100.00	Replace Ballast & Lamps	0.75	71	71	53.25
Office	2x4 Electronic Fluorescent	1	3	100	100.00	Replace Ballast & Lamps	0.75	71	71	53.25
Recr/Clerical	2x4 Electronic Fluorescent	4	3	100	400.00	Replace Ballast & Lamps	1.00	71	284	284
Recr/Clerical	2x2 Electronic Fluorescent	1	3	70	70.00	Replace Ballast & Lamps	1.00	42	42	42
Electrical Room	1x4 Electronic Fluorescent	2	2	70	140.00	Replace Ballast & Lamps	0.25	48	96	24
Mechnical Equip	1x4 Electronic Fluorescent	6	2	70	420.00	Replace Ballast & Lamps	0.25	48	288	72
Janitor	1x4 Electronic Fluorescent	1	2	70	70.00	Replace Ballast & Lamps	0.25	48	48	12
Mail/Copy	2x4 Electronic Fluorescent	4	3	100	400.00	Replace Ballast & Lamps	0.75	71	284	213
Staff Lounge	2x4 Electronic Fluorescent	3	3	100	300.00	Replace Ballast & Lamps	0.75	71	213	159.75
Staff Lounge	2x2 Electronic Fluorescent	2	3	70	140.00	Replace Ballast & Lamps	0.75	42	84	63
Staff Lounge	100W Mercury Vapor	1	1	125	125.00	Compact Fluorescent	0.75	57	57	42.75
Central Storage	2x4 Electronic Fluorescent	3	2	70	210.00	Replace Ballast & Lamps	0.75	48	144	108
Central Storage	2x2 Electronic Fluorescent	2	3	70	140.00	Replace Ballast & Lamps	0.75	42	84	63
Storage	2x4 Electronic Fluorescent	1	2	70	70.00	Replace Ballast & Lamps	0.25	48	48	12
Bulk Storage	1x4 Electronic Fluorescent	19	2	70	1330.00	Replace Ballast & Lamps	0.25	48	912	228
Corridor	1x4 Electronic Fluorescent	1	2	70	70.00	Replace Ballast & Lamps	1.00	48	48	48
Corridor	100W Mercury Vapor	4	1	125	500.00	Compact Fluorescent	1.00	57	228	228
Conference	2x4 Electronic Fluorescent	3	3	100	300.00	Replace Ballast & Lamps	1.00	71	213	213
Waiting No. 5	100W Mercury Vapor	4	1	125	500.00	Compact Fluorescent	1.00	57	228	228
Waiting No. 5	Incandescent	4	1	150	600.00	Compact Fluorescent	1.00	26	104	104
				Total Watts Main Building:	**37626.00**			**Total Watts Main Building:**	**22076.00**	**18912.25**

Existing Lighting Data - Police						New Lighting Data - Police				
Location	Fixture Type	# Of Fixtures	Lamps Per Fixture	Watts Per Fixture	Total Watts	Fixture Type	Occupancy Sensor Adjustment Factor	Watts Per Fixture	Total Watts	Total Watts Adjusted
Police Interior	2x4 Electronic Fluorescent	27	3	100	2700.00	Replace Ballast & Lamps	1.00	71	1917	1917
Police Interior	2x4 Magnetic Fluorescent	26	3	115	2990.00	Replace Ballast & Lamps	1.00	71	1846	1846
Police Interior	100W Mercury Vapor	39	1	125	4875.00	Compact Fluorescent	1.00	57	2223	2223
Police Interior	2x2 Electronic Fluorescent	15	3	70	1050.00	Replace Ballast & Lamps	1.00	42	630	630
Police Interior	2x2 Magnetic Fluorescent	15	3	84	1260.00	Replace Ballast & Lamps	1.00	42	630	630
Police Interior	1x4 Electronic Fluorescent	19	2	70	1330.00	Replace Ballast & Lamps	1.00	48	912	912
Police Interior	Incandescent	12	1	150	1800.00	Compact Fluorescent	1.00	27	324	324
Police Interior	2x2 Electronic Fluorescent	6	2	45	270.00	Replace Ballast & Lamps	1.00	33	198	198
Police Interior	Strip Fluorescent	4	3	100	400.00	Replace Ballast & Lamps	1.00	71	284	284
Police Interior	Strip Fluorescent	1	2	70	70.00	Replace Ballast & Lamps	1.00	48	48	48
Police Interior	Undercounter Fluorescent	4	1	40	160.00	Undercounter Fluorescent	1.00	40	160	160

Table7b. Lighting Summary - TBD

Mechanical Systems

The existing chiller serving the Manalapan main building & Police headquarters is an air-cooled Bohn machine rated at 118 tons. Maintenance records performed in June indicate that only 2 of the machines 4 compressors are still functioning and the maximum capacity of the chiller may only be 60 tons at this point. The pumping system is currently a constant volume flow system. The new system will employ a VFD package capable of adjusting flow to the most efficient level. Chilled water flow is constant volume through two 15 HP pumps, one pump runs at a time.

The existing Hydrotherm gas-fired hot water heating boiler has an original efficiency rating of 80% and is rated at 1,200 MBH. Over time the efficiency of a boiler drops causing an increase in gas usage to maintain the same building conditions. The boiler's current efficiency is likely below 70% due to its age. The domestic hot water heater is fairly new and is a small load compared to the HVAC heating boiler. The domestic water heater is not included as part of the energy savings at this time.

There are 5 air handling units (4 on the roof, 1 in the 1st floor mechanical room). All 5 have a chilled water coil and not steam or hot water coil. 4 of the 5 have inoperable inlet guide vanes. Only AHU-2 serving the court room was originally intended to be constant volume. The return fans for AHU- 1 & AHU-4 are turned off at the disconnect switch. Dampers visibly have a considerable amount of air leakage.

There are 57 VAV boxes with hot water reheat throughout the facility.

All the above is served by 27 year old Barber Coleman DDC controls system.

There is a 5 ton split system serving the dispatch area but it is turned off at the disconnect switch. Another small split system serves a data room.

Normal occupancy is achieved through the use of time clocks – the main building side is occupied basically 5 days a week, standard hours. The Police side is occupied to some degree 24/7.

Detailed specifications for the mechanical systems in the project, including HVAC systems, chillers, and motors, are included in the tables below.

Table 8. Motors

					Nameplate Data					
Motor ID	**Number of Identical Units**	**Loading (constant/ variable)**	**Affiliated System**	**Control Type**	**Manufacturer**	**Model Number**	**Motor hp**	**Nominal Efficiency**	**Synchronous Speed (RPM)**	**Type: TEFC or ODP**
Example	1	Constant	Hot Water System Pump	Switch	Baldor	UTC-F9R-334-2	1.5	0.75	1730	ODP
AHU-1 supply fan	1	Constant	AHUs	Switch	Bohn		15	0.84	1,700	ODP
AHU-2 supply fan	1	Constant	AHUs	Switch	Bohn		7.5	0.84	1,700	ODP
AHU-3 supply fan	1	Constant	AHUs	Switch	Bohn		5	0.84	1,700	ODP
AHU-4 supply fan	1	Constant	AHUs	Switch	Bohn		10	0.84	1,700	ODP
AHU-5 supply fan	1	Constant	AHUs	Switch	Bohn		10	0.84	1,700	ODP
AHU-1 return fan	1	Constant	AHUs	Switch	Bohn		2	0.84	1,700	ODP
AHU-2 return fan	1	Constant	AHUs	Switch	Bohn		5	0.84	1,700	ODP
AHU-3 return fan	1	Constant	AHUs	Switch	Bohn		1	0.84	1,700	ODP
AHU-4 return fan	1	Constant	AHUs	Switch	Bohn		3	0.84	1,700	ODP

Table 9. HVAC Schedule

HVAC ID	Equipment Type	Location	Areas Served	Number of Units	Manufacturer	Model #	Year of Mfr	Economizer	Efficiency	
Example	Packaged A/C	Roof	Administration	1	Trane	YSC060	2006	None	12	SEER
AHU-1	Packaged A/C	Roof	2nd flr office	1	Bohn		1983	None	14	EER
AHU-2	Packaged A/C	Roof	court room	1	Bohn		1983	None	14	EER
AHU-3	Packaged A/C	Roof	Police area	1	Bohn		1983	None	14	EER
AHU-4	Packaged A/C	Roof	2nd flr office	1	Bohn		1983	None	14	EER
AHU-5	Built-up	1st floor mech rm	1st fllor	1	Bohn		1983	None	14	EER

HVAC ID	Cooling Capacity (mbh)	Heating Capacity (mbh)	Cooling Type	Heating Type	Supply Air (cfm)	Outside Air (cfm)	Fan HP		Supply Air Control	Heat Recovery	Recovery Efficiency
							Supply	Return			
Example	36.3	103.4	DX	Gas Furnace	1500	150	1	N/A	Constant	N/A	
AHU-1			Chilled Water	None	9500	2850	15	2	VAV 10 - inlet control	N/A	N/A
AHU-2			Chilled Water	None	5950	1785	7.5	5	VAV 10 - inlet control	N/A	N/A
AHU-3			Chilled Water	None	2690	807	5	1	VAV 10 - inlet control	N/A	N/A
AHU-4			Chilled Water	None	9000	2700	10	3	Constant	N/A	N/A
AHU-5			Chilled Water	None	9000	2700	10	3	VAV 10 - inlet control	N/A	N/A

Table 10. Boiler and Domestic Hot Water

Boiler or DHW ID	Location	HVAC or Area Served	Number of Units	Manufacturer	Model Number	Year of Mfr	Equipment Type	Capacity (mbh)	Efficiency (AFUE)	Combustion Fan hp	Feedwater Pump hp	Circulation Pump hp	Pump Control
Example	Boiler Room	Entire Building	2	H. B. Smith	Mills 450A-12	1986	Gas Fired Boiler	200	70	N/A`	N/A	1.5	Constant Volume
HVAC Boiler	1st flr mech room	All but retrofit space	1	Multi Temp	MR1200B	1983	Gas Fired Boiler	1200				5	Constant Volume
Domestic Heater	1st flr mech room	All but retrofit space	1	Universal									

Table 11. Chillers and Condensers

Chiller ID	Location	HVAC Served	# of Units	Manufacturer	Model Number	Year of Mfr	Equipment Type	Capacity (tons)	Type of Refrigerant	ARI Rated Full Load Efficiency (kW/ton)	Integrated Part-load Efficiency (IPLV)	Condenser Type	Tower or Condenser Fan HP	Num. Fans	Condenser Fan Control
Ex	Utility Room	All	1	York Millenium	YKJFBJ4-DHES	2005	Gas Absorption	1600	R134a	0.731	0.667	Water-cooled	75	1	VFD
Chiller	Outside	All but retrofit space	1	Bohn	RV81413B	1983	Screw	120	R22	1.8		Air-cooled	7.5	4	Single Speed

Operation and Maintenance

Building is clean, and routine maintenance is done regularly, Due to the age of the systems occupant comfort is a problem

Process Equipment and Systems

Standard office equipment

Other Energy Consuming Equipment and Systems

A dispatch center

SECTION II – FACILITY SIMULATION

This analysis was conducted using the facility modeling software, Trace 700 Version 6.2.6.5, by Tozour Energy Systems. Simulation results can be found in Appendix B.

Major Assumptions Used to Establish the Baseline

Office side is occupied 50 hours per week, Police side is 24/7.

Detailed modeling assumptions can be found in Separate attachment.

Baseline Facility Variables

Supporting calculations can be found in Appendix C. (No additional modeling tools were used)

Calibration

The simulation model has been calibrated to actual utility bills for the project, resulting in the following accuracy statistics:

Table 12. Model Calibration Statistics

Accuracy Statistics: Overall	Select Pass/Fail:	Pass
	Statistics	Maximum
MBE	2%	5%
CVRMSE	14%	17%
Overall Savings Uncertainty	4%	19%

SECTION III – RECOMMENDED MEASURES

This section describes the energy efficiency opportunities assessed and recommended for this project. In accordance with version 2.0 of the P4P Program Guidelines, a comprehensive suite of potential energy reduction opportunities has been analyzed for this project.

The estimated annual energy savings based on the list of recommended measures in Table 13 and Table 14 include a natural gas reduction of 14% and a kWh electricity reduction of 25%,

Table 13. Recommended Measures – Description

Measure Name		Measure Category	Measure Details (Describe Equipment/Controls to be Installed)	Fuel Affected	Quantity	Equipment Replaced (optional)
Ex	Boiler replacement	Hot Water Boiler (Gas)	Replace boilers with (2) 2000 mbh modular condensing boilers rated at 90% CE or higher	Natural Gas	2	Hot Water Boiler (Gas)
1	Cooling & Heating Plant Upgrade	Air Cooled Chiller (Electric)	Replace Chiller & Boiler. New pumps for both, VFD for chilled water pumps, test & balalnce save both electric & gas	Electric	2	Air Cooled Chiller (Electric)
2	Lighting Upgrade	Fluorescent Fixtures	Lighting upgrade T12 to T8 and CFL	Electric	537	Fluorescent Fixtures

Table 14. Recommended Measures - Cost and Energy Savings

	Measure Name	Installed Cost (incl. design)	Annual Energy Savings					Demand Savings	Annual O&M Savings	Annual Cost Savings	Measure Life	Simple Payback	Life Cycle Savings	IRR
		$	kWh	Gas MMBtu	Steam MMBtu	Fuel Oil MMBtu	Other MMBtu	kW	$	$	years	years	$	%
1	Cooling & Heating Plant Upgrade	$177,394	125,045	309	0	0	0	31.0	$0	$24,362	20	7.28	$185,051	12.4%
2	Lighting Upgrade	$44,200	121,419	-97	0	0	0	18.0	$0	$18,782	15	2.35	$180,018	42.3%
	CM Fees	$100,892	*Overall project management, all fees associated with specific measures should be noted above.*											
	Partner Fees	$0	*Per Partner Contract*											
	TOTALS	$322,486.00	246,464	212	0	0	0	49.0	$0	$43,144		7.47	$264,177	11.3%

Measures Recommended for the Project

Measure #1 – Cooling & Heating Plant Upgrade

Description of Improvement

Chiller Project will consist of removal and demolition of existing chiller, installation of new chiller including all associated mounting, electrical, and piping work. Installation of new chilled water pumps with premium efficiency pump motors and a Variable Frequency Drive (VFD) Package including system balancing.

The existing chiller will be replaced with the highest efficiency model available in an air-cooled model. The highest efficiency available for an air-cooled chiller is an EER of 10.5 = kW/Ton of 1.14. This efficiency rating is 9.8% better than what will be required by ASHRAE 90.1-2010 which requires an EER of 9.562. The installation of a high efficiency machine will improve facility comfort while driving down energy costs.

Premium efficiency electric motors will help to optimize pumping systems efficiency, reduce electrical power consumption and costs, and improve system reliability. Premium efficiency motors run cooler, last longer, and require less maintenance than the existing standard efficiency motors. Premium efficiency motors can be as high as 95% efficient as opposed to standard efficiency motors of 78% to 88%. Premium efficiency motors are also designed to operate well at varying speed allowing variable Frequency Drive (VFD) installations where applicable. Energy savings from VFD motors will increase savings up to 20%.

Testing & Balancing (T&B) of chilled water systems is a crucial task in the process of ensuring optimum energy efficiency of chillers and the units they serve. T&B will match the output of each system to its load. HVAC systems are balanced to deliver the proper amount of water to maintain comfort and efficiency. Too much or too little chilled water delivered to a cooling load results in energy waste as well as occupant discomfort.

Boiler Project consists of removal and demolition of existing boiler, installation of modular boilers, includes all gas and hot water piping and associated electrical work. Installation of new pumps with premium efficiency motors including system balancing.

Modular boilers have smaller footprints than larger models simplifying transportation and installation. Since boiler efficiency ratings are better with a higher load, a series of smaller boilers is ideal for energy savings by running only when they are needed. Compared to the larger hot water boilers which often run at a lower efficiency to satisfy a low heating load, modular boilers can fire at higher (more efficient) rates and meet the needs of the building. The results are less gas usage and lower energy costs.

Premium efficiency electric motors will help to optimize pumping systems efficiency, reduce electrical power consumption and costs, and improve system reliability. Premium efficiency motors run cooler, last longer, and require less maintenance than the existing standard efficiency motors. Premium efficiency motors can be as high as 95% efficient as opposed to standard efficiency motors of 78% to 88%. Premium efficiency motors are also designed to operate well at varying speed allowing variable Frequency Drive (VFD) installations where applicable. Energy savings from VFD motors for the chilled water pumps will increase savings up to 20% Hot water system to remain constant volume..

Testing & Balancing (T&B) of chilled water systems is a crucial task in the process of ensuring optimum energy efficiency of chillers & boilers and the units they serve. T&B will match the output of each system to its load. HVAC systems are balanced to deliver the proper amount of water to maintain comfort and efficiency. Too much or too little chilled or hot water delivered to a cooling load results in energy waste as well as occupant discomfort.

Existing Conditions

The existing chiller serving the Manalapan main building & Police headquarters is an air-cooled Bohn machine rated at 118 tons. Maintenance records performed in June indicate that only 2 of the machines 4 compressors are still functioning and the maximum capacity of the chiller may only be 60 tons at this point. The pumping system is currently a constant volume flow system. The new system will employ a VFD package capable of adjusting flow t the most efficient level.

The existing Hydrotherm gas-fired hot water heating boiler has an original efficiency rating of 80% and is rated at 1,200 MBH. Over time the efficiency of a boiler drops causing an increase in gas usage to maintain the same building conditions. The domestic hot water heater is fairly new and is a small load compared to the HVAC heatin boiler. The domestic water heater is not included as part of the energy savings at this time. This ECM will save natural gas through greatly improved efficiency.

Assumptions

Measure #2 – Lighting Upgrade

Description of Improvement

Project consists of retrofit or replacement of 537 existing light fixtures and 48 occupancy sensors and photocells with all associated electrical work.

Every effort has been made to standardize the installed components to reduce operational and maintenance costs over the life of the installed system. Energy savings calculations are based upon hours of operation for each area surveyed. These hours are determined through a combination of information obtained from the energy audit as well as commonly accepted industry standards. Ballast wattages presented within the energy savings analysis are based upon the manufacturers' reported technical data.

This project will retrofit the existing lighting system with newer technology energy efficient lamps, ballasts, and light fixtures. The lighting retrofit design incorporates the replacement of lamps and ballasts as well as the replacement of light fixtures when the fixture is in poor condition.

Areas of the Facility to be retrofitted with new lamps & ballasts include: Office areas, Court rooms,

Storage, Police interior, Staff lounges, & Corridors

Existing Conditions

The main building and Police headquarters are lighted by a combination of T12 fluorescent fixtures, 100 Watt mercury vapor fixtures and incandescent bulbs. The lighting on the Police side is on 24 hours per day, 7 days per week. The main building side lighting is on approximately 50 hours per week. The lighting upgrade includes a combination of T-8 and compact fluorescent lights and new fixtures.

Assumptions

Energy Efficiency Options Examined But Not Recommended

The following measures were analyzed but not recommended for the reasons discussed below.

(1) <Ground Source, Geo thermal chiller for cooling & heating (unacceptable payback)

SECTION IV – FINANCING PLAN

Table 15 includes a description of the funding sources the Owner will use to finance implementation of the recommended measures. The table presents the estimated costs associated with implementing the recommended measures to achieve the energy savings performance target, along with the sources of funding planned to cover those costs.

Table 15. Financing Plan

Total Cost of Improvements	$221,594
Construction Management Fees	$100,892
P4P Partner Fees	$0
TOTAL COSTS	**$322,486**

		Committed or Requested
Anticipated NJOCE Incentives	$64,522	
ESIUP Funded	$257,964	
TOTAL FUNDING	**$322,486**	

SECTION V – IMPLEMENTATION SCHEDULE

Table 16 represents the implementation schedule for the recommended measures.

Table 16. Implementation Schedule

	Measure	Delivery Method	Estimated Construction Start	Estimated Completion Date
1	Cooling & Heating Plant Upgrade	Contracted Bid	6/1/2001	12/31/2011
2	Lighting Upgrade	Contracted Bid	6/1/2011	12/31/2001

SECTION VI – METERING PLAN

This section describes pre-retrofit metering activities that were conducted at the facility, performed according to Section 4 of the P4P Program Guidelines. Detailed pre-metering results can be found in Appendix E.

Chiller
Method: performance test results and measured energy usage will be verified using IPMVP method A & B (single & multiple variable) Single variable is peak load of chiller, multiple variable includes estimated run hours based on historical ambient conditions

Assumptions

Schedule: TBD

Boiler
Method: Same methods will be employed as for chiller above

Assumptions:

Schedule: TBD

Lighting
Method: measurement of each lighting circuit voltage & current before & after retrofit with estimated occupancy hours

Assumptions

Schedule: TBD

APPENDIX A:
EPA Portfolio Manager *Statement of Energy Performance*

STATEMENT OF ENERGY PERFORMANCE
Manalapan Township Building

Building ID: 2637177
For 12-month Period Ending: December 31, 2010[1]
Date SEP becomes ineligible: N/A

Date SEP Generated: March 04, 2011

Facility	**Facility Owner**	**Primary Contact for this Facility**
Manalapan Township Building 120 County Rt 522 Manalapan , NJ 07726	Tozour Energy Systems 741 1st Ave King of Prussia, PA 19406	Brian Peifer 741 1st Ave King of Prussia, PA 19406

Year Built: 1983
Gross Floor Area (ft²): 30,019

Energy Performance Rating[2] (1-100) 10

Site Energy Use Summary[3]	
Electricity - Grid Purchase(kBtu)	3,350,584
Natural Gas (kBtu)[4]	1,487,000
Total Energy (kBtu)	4,837,584

Energy Intensity[5]	
Site (kBtu/ft²/yr)	161
Source (kBtu/ft²/yr)	425

Emissions (based on site energy use)	
Greenhouse Gas Emissions ($MtCO_2e$/year)	N/A

Electric Distribution Utility
N/A

National Average Comparison	
National Average Site EUI	100
National Average Source EUI	264
% Difference from National Average Source EUI	61%
Building Type	Office

Stamp of Certifying Professional

Based on the conditions observed at the time of my visit to this building, I certify that the information contained within this statement is accurate.

Meets Industry Standards[6] **for Indoor Environmental Conditions:**

Ventilation for Acceptable Indoor Air Quality	N/A
Acceptable Thermal Environmental Conditions	N/A
Adequate Illumination	N/A

Certifying Professional
Brian Peifer
741 1st Ave
King of Prussia, PA 19406

Notes:
1. Application for the ENERGY STAR must be submitted to EPA within 4 months of the Period Ending date. Award of the ENERGY STAR is not final until approval is received from EPA.
2. The EPA Energy Performance Rating is based on total source energy. A rating of 75 is the minimum to be eligible for the ENERGY STAR.
3. Values represent energy consumption, annualized to a 12-month period.
4. Natural Gas values in units of volume (e.g. cubic feet) are converted to kBtu with adjustments made for elevation based on Facility zip code.
5. Values represent energy intensity, annualized to a 12-month period.
6. Based on Meeting ASHRAE Standard 62 for ventilation for acceptable indoor air quality, ASHRAE Standard 55 for thermal comfort, and IESNA Lighting Handbook for lighting quality.

ENERGY STAR® Data Checklist for Commercial Buildings

In order for a building to qualify for the ENERGY STAR, a Professional Engineer (PE) or a Registered Architect (RA) must validate the accuracy of the data underlying the building's energy performance rating. This checklist is designed to provide an at-a-glance summary of a property's physical and operating characteristics, as well as its total energy consumption, to assist the PE or RA in double-checking the information that the building owner or operator has entered into Portfolio Manager.

Please complete and sign this checklist and include it with the stamped, signed Statement of Energy Performance.
NOTE: You must check each box to indicate that each value is correct, OR include a note.

CRITERION	VALUE AS ENTERED IN PORTFOLIO MANAGER	VERIFICATION QUESTIONS	NOTES	☑
Building Name	Manalapan Township Building	Is this the official building name to be displayed in the ENERGY STAR Registry of Labeled Buildings?		☐
Type	Office	Is this an accurate description of the space in question?		☐
Location	120 County Rt 522, Manalapan , NJ 07726	Is this address accurate and complete? Correct weather normalization requires an accurate zip code.		☐
Single Structure	Single Facility	Does this SEP represent a single structure? SEPs cannot be submitted for multiple-building campuses (with the exception of acute care or children's hospitals) nor can they be submitted as representing only a portion of a building		☐

Police Station (Medical Office)

CRITERION	VALUE AS ENTERED IN PORTFOLIO MANAGER	VERIFICATION QUESTIONS	NOTES	☑
Gross Floor Area	9,270 Sq. Ft.	Does this square footage include all supporting functions such as kitchens and break rooms used by staff, storage areas, administrative areas, elevators, stairwells, atria, vent shafts, etc. Also note that existing atriums should only include the base floor area that it occupies. Interstitial (plenum) space between floors should not be included in the total. Finally gross floor area is not the same as leasable space. Leasable space is a subset of gross floor area.		☐
Number of Workers	25	Is this the number of employees present during the main shift? Note this is not the total number of employees or visitors who are in a building during an entire 24 hour period. For example, if there are two daily 8 hour shifts of 100 workers each, the Workers on Main Shift value is 100.		☐
Weekly operating hours	168 Hours	Is this the total number of hours per week that the Medical Office space is 75% occupied? This number should exclude hours when the facility is occupied only by maintenance, security, or other support personnel. For facilities with a schedule that varies during the year, "operating hours/week" refers to the total weekly hours for the schedule most often followed.		☐
Percent Cooled	100 %	Is this the percentage of the total floor space within the facility that is served by mechanical cooling equipment?		☐
Percent Heated	100 %	Is this the percentage of the total floor space within the facility that is served by mechanical heating equipment?		☐

Township Operation (Office)

CRITERION	VALUE AS ENTERED IN PORTFOLIO MANAGER	VERIFICATION QUESTIONS	NOTES	☑
Gross Floor Area	20,749 Sq. Ft.	Does this square footage include all supporting functions such as kitchens and break rooms used by staff, storage areas, administrative areas, elevators, stairwells, atria, vent shafts, etc. Also note that existing atriums should only include the base floor area that it occupies. Interstitial (plenum) space between floors should not be included in the total. Finally gross floor area is not the same as leasable space. Leasable space is a subset of gross floor area.		☐

Weekly operating hours	50 Hours	Is this the total number of hours per week that the Office space is 75% occupied? This number should exclude hours when the facility is occupied only by maintenance, security, or other support personnel. For facilities with a schedule that varies during the year, "operating hours/week" refers to the total weekly hours for the schedule most often followed.		☐
Workers on Main Shift	75	Is this the number of employees present during the main shift? Note this is not the total number of employees or visitors who are in a building during an entire 24 hour period. For example, if there are two daily 8 hour shifts of 100 workers each, the Workers on Main Shift value is 100. The normal worker density ranges between 0.3 and 5.3 workers per 1000 square feet (92.8 square meters)		☐
Number of PCs	80	Is this the number of personal computers in the Office?		☐
Percent Cooled	50% or more	Is this the percentage of the total floor space within the facility that is served by mechanical cooling equipment?		☐
Percent Heated	50% or more	Is this the percentage of the total floor space within the facility that is served by mechanical heating equipment?		☐

ENERGY STAR® Data Checklist for Commercial Buildings

Energy Consumption

Power Generation Plant or Distribution Utility:

Fuel Type: Electricity		
Meter: Electric Meter (kWh (thousand Watt-hours)) **Space(s):** Entire Facility **Generation Method:** Grid Purchase		
Start Date	**End Date**	**Energy Use (kWh (thousand Watt-hours))**
12/01/2010	12/31/2010	59,360.00
11/01/2010	11/30/2010	74,080.00
10/01/2010	10/31/2010	85,280.00
09/01/2010	09/30/2010	104,960.00
08/01/2010	08/31/2010	112,000.00
07/01/2010	07/31/2010	105,440.00
06/01/2010	06/30/2010	69,920.00
05/01/2010	05/31/2010	89,280.00
04/01/2010	04/30/2010	65,120.00
03/01/2010	03/31/2010	70,160.00
02/01/2010	02/28/2010	75,200.00
01/01/2010	01/31/2010	71,200.00
Electric Meter Consumption (kWh (thousand Watt-hours))		**982,000.00**
Electric Meter Consumption (kBtu (thousand Btu))		**3,350,584.00**
Total Electricity (Grid Purchase) Consumption (kBtu (thousand Btu))		**3,350,584.00**
Is this the total Electricity (Grid Purchase) consumption at this building including all Electricity meters?		☐

Fuel Type: Natural Gas		
Meter: Gas (therms) **Space(s):** Entire Facility		
Start Date	**End Date**	**Energy Use (therms)**
12/01/2010	12/31/2010	3,450.00
11/01/2010	11/30/2010	1,850.00
10/01/2010	10/31/2010	610.00
09/01/2010	09/30/2010	140.00
08/01/2010	08/31/2010	140.00
07/01/2010	07/31/2010	130.00
06/01/2010	06/30/2010	140.00
05/01/2010	05/31/2010	170.00
04/01/2010	04/30/2010	170.00
03/01/2010	03/31/2010	1,740.00

02/01/2010	02/28/2010	2,760.00
01/01/2010	01/31/2010	3,570.00
Gas Consumption (therms)		**14,870.00**
Gas Consumption (kBtu (thousand Btu))		**1,487,000.00**
Total Natural Gas Consumption (kBtu (thousand Btu))		**1,487,000.00**
Is this the total Natural Gas consumption at this building including all Natural Gas meters?		☐

Additional Fuels	
Do the fuel consumption totals shown above represent the total energy use of this building? Please confirm there are no additional fuels (district energy, generator fuel oil) used in this facility.	☐

On-Site Solar and Wind Energy	
Do the fuel consumption totals shown above include all on-site solar and/or wind power located at your facility? Please confirm that no on-site solar or wind installations have been omitted from this list. All on-site systems must be reported.	☐

Certifying Professional

(When applying for the ENERGY STAR, the Certifying Professional must be the same PE or RA that signed and stamped the SEP.)

Name: _____ Date: _____

Signature: _____

Signature is required when applying for the ENERGY STAR.

APPENDIX B: Simulation Reports

(Attached separately)

APPENDIX C: Modeling Assumptions

(Stated above)

Supporting Calculations for Independent Variables

(None)

APPENDIX D: Supporting Calculations

(None)

APPENDIX E: Pre-Retrofit Metering Results

(Pending)

APPENDIX F: Combined Heat and Power System

(None)

Energy Savings Plan (ESIP)

Contents

The Sustainability Services Center..... 2
Overview..... 2
I. Building Performance Management | Overview..... 3
Example of a Chiller Analysis 4
II. Building Performance Management | Benefits 7
III. Building Performance Management – Success Story..... 12
IV. Sustainability Services (Metering)..... 14
V. Sustainability Services (Remote Alarm Monitoring and analysis)..... 16

The Sustainability Services Center

Overview

Sustainability Services at Tozour Energy Systems, Inc. in King of Prussia takes building automation to the next level. Most facilities have some type of control system, otherwise known as a building automation system. However, in many cases that control system is very much underutilized. The Sustainability Services takes advantage of these inherent features of the control system and the vast amount of information it contains to show how a facility is really performing. This document will describe how Sustainability Services works and the benefits they provide.

I. Sustainability ‖ Building Performance Management | Overview

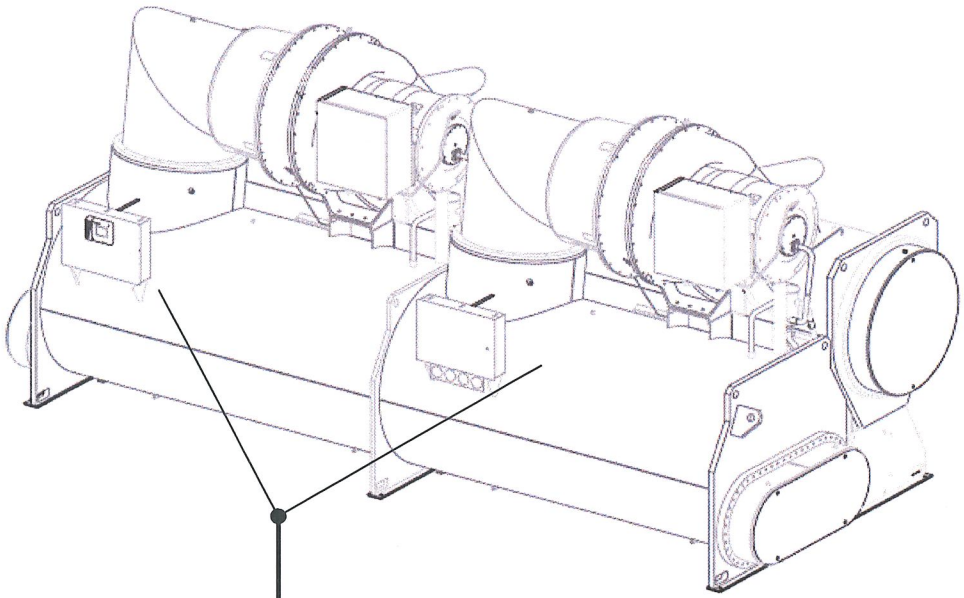
II. Sustainability ‖ Building Performance Management | Benefits

III. Sustainability ‖ Building Performance Management | How it Works

IV. Sustainability ‖ Building Performance Management | Metering

V. Sustainability ‖ Remote Alarm Monitoring and analysis

I. Building Performance Management | Overview



System data is collected continually by utilizing the trending features of the Building Automation System.

30-Jul-07	Chw Set Point	Chw Supply Temp	Chw Return Temp	Cond Set Point	Cond Entering Temp	Cond Leaving Temp	Outdoor Air Temp	Outdoor Air Rh%	Outdoor Air Wet Bulb	Refrigerant Temp	Condenser Approach	KW per Ton	Phase A Volts	Phase A Amps
10:15 AM	42	41.8	51.1	85	86.7	95.1	82	74	76	94	1.1	0.65	460	2020
10:30 AM	42	41.9	50.9	85	86.3	95	82	74	76	94	1	0.66	460	2020
10:45 AM	42	42	51.3	85	86	95.8	82	74	76	94.3	1.5	0.67	460	2020
11:00 AM	42	42.2	51.3	85	86.3	95.3	82	74	76	94.3	1	0.65	460	2019
11:15 AM	42	42.5	51.3	85	86.5	95.1	82	74	76	94	1.1	0.65	460	2019
11:30 AM	42	43	51.1	85	86.9	94.9	83	74	76	94.3	0.6	0.66	460	2020
11:45 AM	42	42.5	52	85	87	95.4	83	73	77	94.1	1.3	0.65	459	2020
12:00 PM	42	42.1	51.8	85	86.9	95.5	83	73	77	94.5	1	0.65	459	2021
12:15 PM	42	42.3.	52	85	86.4	95.5	83	73	77	94.2	1.3	0.66	460	2021
12:30 PM	42	41.8	51.3	85	86.3	96	83	72	77	94.3	1.7	0.67	460	2021
12:45 PM	42	41.9	51.3	85	86.6	96.1	84	72	77	94.6	1.5	0.68	460	2022
1:00 PM	42	42	51.3	85	87.1	96.2	84	72	78	95	1.2	0.68	460	2022
1:15 PM	42	42.2	51.1	85	87.5	96.2	84	71	78	95.2	1	0.65	460	2021
1:30 PM	42	42.5	52	85	87.6	96.4	85	71	78	95.2	1.2	0.65	460	2023
1:45 PM	42	43	51.8	85	87.8	96.8	85	71	78	95.2	1.6	0.67	460	2023
2:00 PM	42	42.5	51.1	85	88.3	97.2	86	70	78	95.3	1.9	0.68	459	2024
2:15 PM	42	42.1	50.9	85	88.4	97.2	87	70	79	95.6	1.6	0.69	459	2025
2:30 PM	42	42.2	51.3	85	88.8	97.5	87	69	79	95.7	1.8	0.68	460	2025
2:45 PM	42	42.5	51.3	85	88.7	97.7	88	69	80	96	1.7	0.69	460	2024
3:00 PM	42	43	52	85	89	98.1	88	68	80	96.5	1.6	0.68	460	2024
3:15 PM	42	41.8	51.3	85	89	98.4	89	68	80	96.5	1.9	0.67	460	2024
3:30 PM	42	41.9	51.3	85	89.1	98.4	89	67	80	96.6	1.8	0.68	460	2025
3:45 PM	42	42	51.3	85	89.2	98.9	90	67	81	96.7	2.2	0.68	460	2025
4:00 PM	42	42.2	51.1	85	89.4	99.5	90	66	81	96.7	1.8	0.66	460	2026
4:15 PM	42	42.5	51.8	85	89.6	99.9	90	65	81	96.8	2.1	0.66	459	2026
4:30 PM	42	43	52	85	90	99	89	64	81	97	2	0.67	459	2025
4:45 PM	42	42.5	51.3	85	90	99.1	89	65	81	97.1	2	0.67	460	2025

Chiller 12-5 Overall		
Mon	10/5/2009	10
Tue	10/6/2009	10
Wed	10/7/2009	9
Thu	10/8/2009	8
Fri	10/9/2009	5
Sat	10/10/2009	6
Sun	10/11/2009	7

Performance Key	
8 - 10	Optimum Performance
5 - 7	Fair Performance
0 - 4	Inefficient Performance
NA	Insufficient Data

A custom performance report card is generated from the thousands of trended data readings. The chart above shows overall Chiller performance which is derived from the performance of every available discreet Chiller control loop and parameter as shown in the chart below.

Chilled water Supply Temp Control	9	Evaporator Refrigerant Pressure	10
Condenser Water Temp Control	7	Condenser Refrigerant Pressure	10
Evaporator Approach Temp	9	Monthly Runtime Compressor A	10
Condenser Approach Temp	10	Monthly Runtime Compressor B	10
KW / Ton	9	Entering Oil Temp Compressor A	9
Evaporator Refrigerant Temp	8	Entering Oil Temp Compressor B	9
Condenser Refrigerant temp	9	Unit Downtime	10

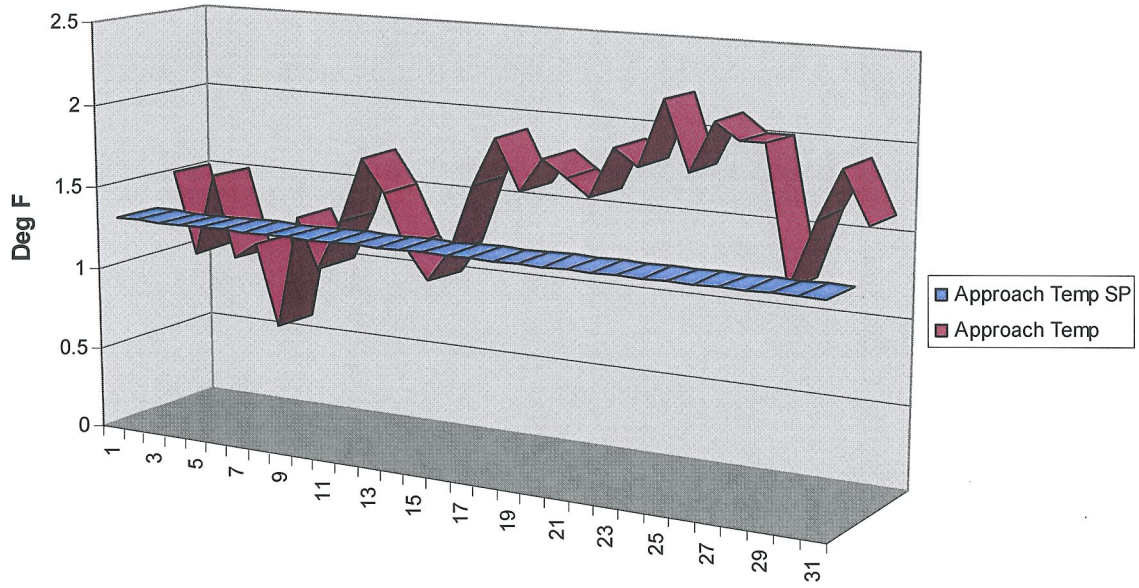
Each report includes an analysis of suspected issues and indicates which pieces of equipment need attention.

Example of a Chiller Analysis

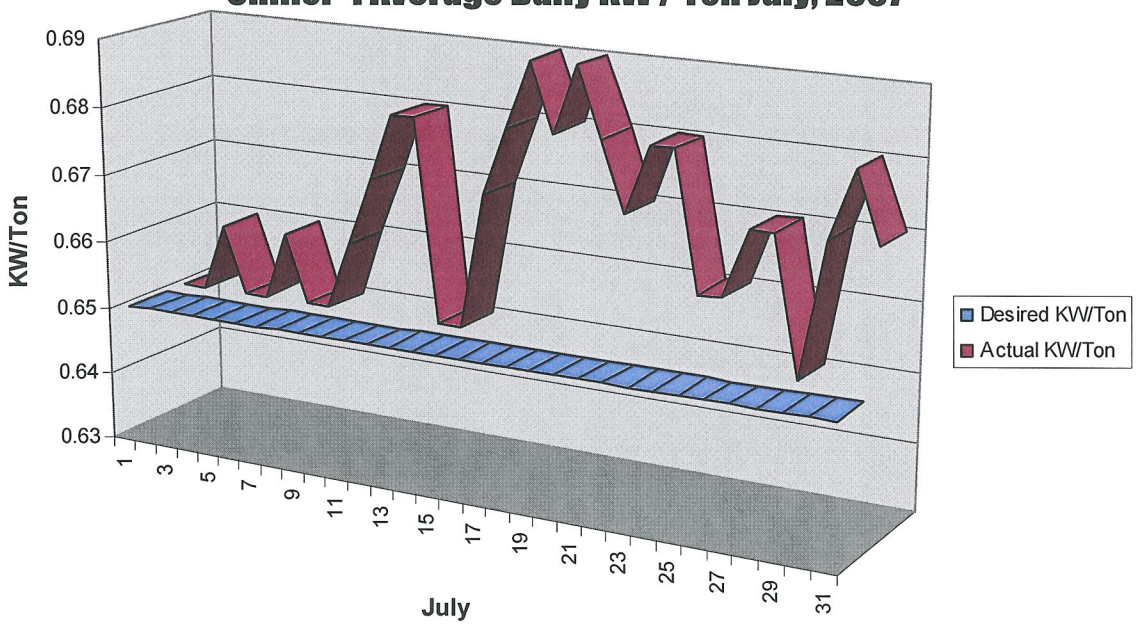
Higher than normal Condenser water temperature due to excessive outdoor air wet bulb temperature (>78 deg F) recorded during the week of October 5th, 2009. Performance calculations have been modified to accommodate this condition.

Individual control loop data can be displayed in a number of formats. The graphs below demonstrate discreet chiller parameters verses desired set points.

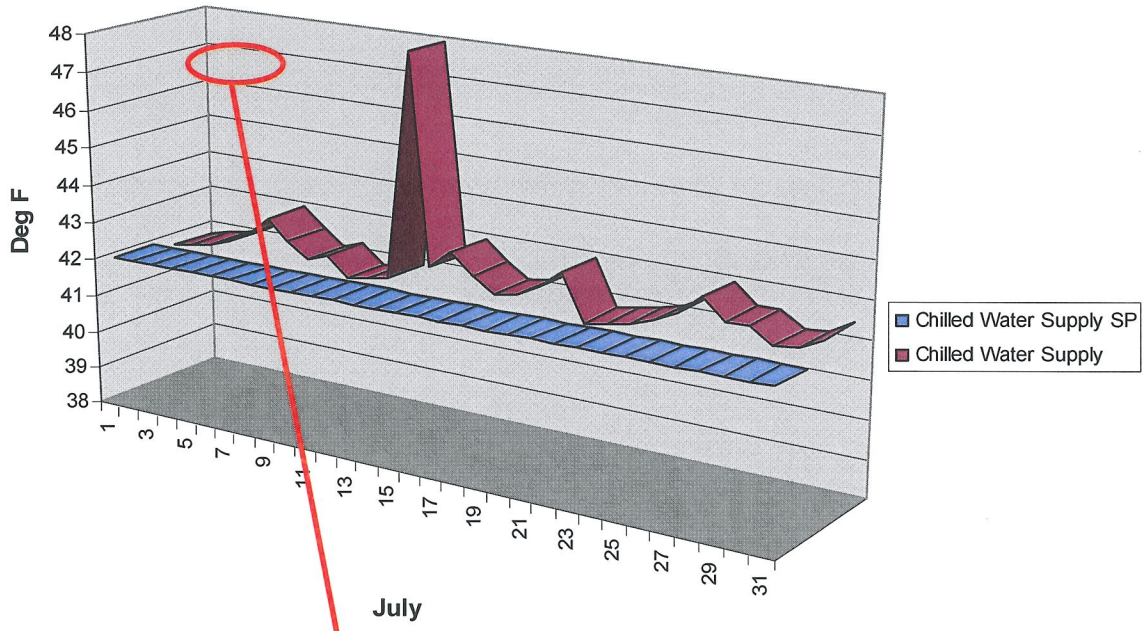
Chiller-1 Average Daily Condenser Approach Temp July, 2007



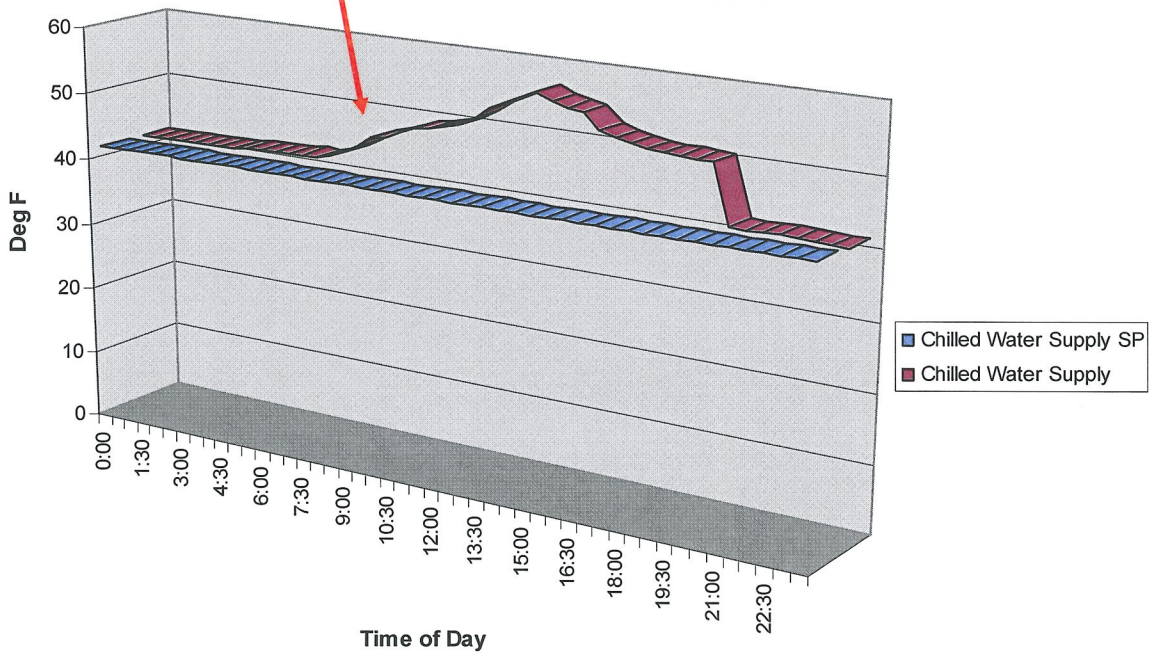
Chiller-1 Average Daily KW / Ton July, 2007



Chiller-1 Average Daily Chilled Water Supply Temp



July 14 Chiller 1 Chilled Water Supply Temp



Data helps to indicate where the root cause of the problems is located. The charts above show chilled water temperature performance for the month of July and a single day when chilled water temp was higher than set point. The accompanying data helps guide technical personnel to the cause of any control or mechanical issue.

II. Building Performance Management | Benefits

A clear, comprehensive, and objective report of how the facility's systems are actually performing. There is far too much data contained in a building automation system (BAS) to be effectivly analyzed all of the time. Sustainability Services uses the built-in, often underutilyzed capabilities of the BAS to create simple to understand building report cards, where the true performance of the facility's systems can be understood at a glance.

Week to week and monthly summaries. Sustainability Services provides a performance history of facility systems allowing in depth analysis of building and equipment seasonal trends.

Constant commissioning of the facility's systems. Using Sustainability Services to constantly monitor building performance is like having a technician monitoring and analysis, analyzing, and optimizing every point in the BAS system 24/7/365.

The means to discover a developing equipment problem before it becomes a costly failure. The reports will show subtle equipment degredation that will usually go un-noticed by building occupants. Catching a problem early before it becomes a major failure will greatly reduce occupant discomfort and cost.

The means to perform conditioned based maintenance and repair activities. The reports will clearly show when equipment is in need of attention. Traditionally, equipment maintenance is performed on a calender scheduled basis. While most equipment does require some regular maintenance (filter changes, grease, etc.) Sustainability Services utilizes the technology of the BAS to notify the maintenance staff of the optimal time to perform equipment analysis, calibration and/or repair.

Quick assesments on the effectiveness of maintenance and repair. Often it will be unclear for a time whether maintenance or repair perfromed was actually effective. Subsequent building report cards will allow the immediate determination of the effectiveness of the work recently done on the facility's systems by showing the before and after results.

A reduction in the manpower cost of maintenance and repair. Not only will the reports display which equipment needs attention, they will actually show what parts, parameters, or algorithms of that equipment may be starting to work ineffectively. This saves time for the technician as a large part of the system trouble-shooting has allready been completed. In addition, maintenance for systems that are automatically deemed to be performing optimally can be deferred, saving time for the immediate issues.

The ability to quickly discover operational energy savings opportunities. Constantly monitoring and analysis facility systems allows for adjustment and calibration keeping the equipment running at optimum efficiency. BAS systems and mechanical equipment will eventually drift away from their normal operationg standards. This causes an inherent increase in the cost of equipment operation due to set point "hunting" or other issues with moving parts like valves and dampers. When BAS systems and equipment can maintain proper operating while doing less work, it takes less utilities to run them.

The means to predict and repair situations that may shorten the life cycle of the facility's systems. Collecting, analyzing, and optimizing all of all of a systems essential data is powerful. Sustainability Services provides the means to using the available data to not only assess how the systems are performing during the present and near future, but it also provides a picture of how equipment may be expected to perform years in the future. The data dispalyed in these building report cards can be calculated to show how current equipment operation and maintenance will positively or negatively impact the life cycle of that equipment. Furthermore, this powerfull data may be considered when planning capital and facility renewal budgeting.

III. Building Performance Management – How It Works

	RTU-1	RTU-2	Discrete Loop
Mon	9	9	*Static Pressure Performance*
	8	8	*Supply Temperature Performance*
	8	9	*Space Temperature Performance*
	10	10	*Speed Drive Performance*
Tue	8	8	*Static Pressure Performance*
	9	9	*Supply Temperature Performance*
	9	10	*Space Temperature Performance*
	10	10	*Speed Drive Performance*
Wed	9	9	*Static Pressure Performance*
	8	8	*Supply Temperature Performance*
	8	9	*Space Temperature Performance*
	10	10	*Speed Drive Performance*
Thu	9	9	*Static Pressure Performance*
	8	8	*Supply Temperature Performance*
	9	9	*Space Temperature Performance*
	10	10	*Speed Drive Performance*
Fri	9	8	*Static Pressure Performance*
	9	9	*Supply Temperature Performance*
	9	9	*Space Temperature Performance*
	10	10	*Speed Drive Performance*
Sat	8	9	*Static Pressure Performance*
	8	9	*Supply Temperature Performance*
	10	10	*Space Temperature Performance*
	10	10	*Speed Drive Performance*
Sun	UNOCC	UNOCC	*Static Pressure Performance*
	UNOCC	UNOCC	*Supply Temperature Performance*
	UNOCC	UNOCC	*Space Temperature Performance*
	UNOCC	UNOCC	*Speed Drive Performance*

BUILDING OVERALL		
Mon	3/22/2010	9
Tue	3/23/2010	9
Wed	3/24/2010	9
Thur	3/25/2010	8
Fri	3/26/2010	10
Sat	3/27/2010	UNOCC
Sun	3/28/2010	UNOCC

PERFORMANCE KEY	
8 - 10	Optimum Performance
5 - 7	Efficient Performance
1 - 4	Improvements Possible
0	Operating Inefficiently
	Unoccupied

After the installation period, the building's HVAC equipment will be commissioned to run optimally. To perform Building Performance Monitoring and analysis, the individual control loops and parameters in the HVAC systems are calculated into an overall performance rating.

RTU-2		RTU-1	Discrete Loop
6	Mon	8	Static Pressure Performance
8		8	Supply Temperature Performance
7		8	Space Temperature Performance
6		8	Speed Drive Performance
7	Tue	8	Static Pressure Performance
9		8	Supply Temperature Performance
7		8	Space Temperature Performance
7		7	Speed Drive Performance
7	Wed	9	Static Pressure Performance
8		8	Supply Temperature Performance
7		7	Space Temperature Performance
7		8	Speed Drive Performance
7	Thu	8	Static Pressure Performance
9		9	Supply Temperature Performance
8		7	Space Temperature Performance
8		8	Speed Drive Performance
7	Fri	9	Static Pressure Performance
9		9	Supply Temperature Performance
7		8	Space Temperature Performance
8		8	Speed Drive Performance
UNOCC	Sat	7	Static Pressure Performance
UNOCC		8	Supply Temperature Performance
UNOCC		8	Space Temperature Performance
UNOCC		7	Speed Drive Performance
UNOCC	Sun	UNOCC	Static Pressure Performance
UNOCC		UNOCC	Supply Temperature Performance
UNOCC		UNOCC	Space Temperature Performance
UNOCC		UNOCC	Speed Drive Performance

BUILDING OVERALL		
Mon	1/4/2010	7
Tue	1/5/2010	7
Wed	1/6/2010	7
Thur	1/7/2010	7
Fri	1/8/2010	7
Sat	1/9/2010	6
Sun	1/10/2010	UNOCC

PERFORMANCE KEY	
8 - 10	Optimum Performance
5 - 7	Efficient Performance
1 - 4	Improvements Possible
0	Operating Inefficiently
	Unoccupied

Over time the equipment begins to drift away from the set-points

	RTU-1	RTU-2	Discrete Loop
Mon	5	5	Static Pressure Performance
	4	10	Supply Temperature Performance
	8	2	Space Temperature Performance
	5	5	Speed Drive Performance
Tue	9	8	Static Pressure Performance
	9	10	Supply Temperature Performance
	8	6	Space Temperature Performance
	10	4	Speed Drive Performance
Wed	4	3	Static Pressure Performance
	4	8	Supply Temperature Performance
	8	3	Space Temperature Performance
	3	3	Speed Drive Performance
Thu	2	2	Static Pressure Performance
	6	8	Supply Temperature Performance
	8	5	Space Temperature Performance
	0	2	Speed Drive Performance
Fri	5	6	Static Pressure Performance
	6	7	Supply Temperature Performance
	9	7	Space Temperature Performance
	4	0	Speed Drive Performance
Sat	UNOCC	UNOCC	Static Pressure Performance
	UNOCC	UNOCC	Supply Temperature Performance
	UNOCC	UNOCC	Space Temperature Performance
	UNOCC	UNOCC	Speed Drive Performance
Sun	UNOCC	UNOCC	Static Pressure Performance
	UNOCC	UNOCC	Supply Temperature Performance
	UNOCC	UNOCC	Space Temperature Performance
	UNOCC	UNOCC	Speed Drive Performance

BUILDING OVERALL		
Mon	4/12/2010	5
Tue	4/13/2010	8
Wed	4/14/2010	3
Thur	4/15/2010	1
Fri	4/16/2010	3
Sat	4/17/2010	UNOCC
Sun	4/18/2010	UNOCC

PERFORMANCE KEY	
8 - 10	Optimum Performance
5 - 7	Efficient Performance
1 - 4	Improvements Possible
0	Operating Inefficiently
	Unoccupied

Date Selected

4/12/2010

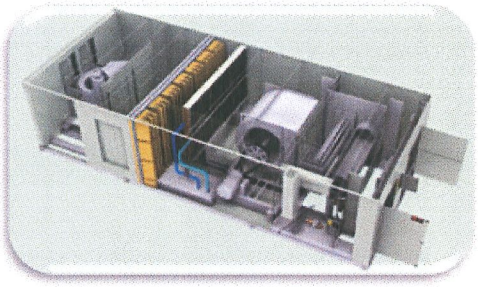
Eventually Unit performance will degrade to the point where people begin to feel uncomfortable or equipment begins to fail generating alarms in the Building Automation System. Performance Management provides a clear path to condition based, proactive maintenance preventing a reactive maintenance call in the future.

Using this type of program has helped Tozour Energy Systems Technicians discover and correct numerous problems long before they became critical problems. The results of this are energy, operational, and capital savings for the facility.

III. Building Performance Management – Success Story

Tozour-Trane
HIGH PERFORMANCE BUILDINGS FOR LIFE

Sustainability Services
Weekly Rooftop Unit Performance Report



Static pressure performance was below setpoint, 3.5 inw, for extended periods during Occupied hours. The VFD output was at 100% during this time, causing supply air and space temperature to be below their respective setpoints.

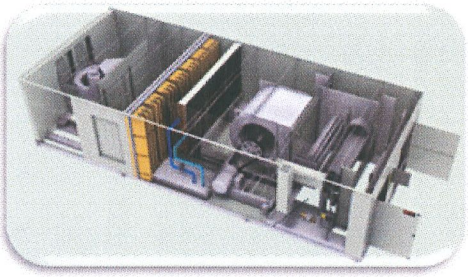
RTU-1	MON	TUES	WED	THUR	FRI	SAT	SUN
	8/16/2010	8/17/2010	8/18/2010	8/19/2010	8/20/2010	8/21/2010	8/22/2010
Overall Unit Performance	4	5	2	5	6	UNOCC	0

8-10 Optimum Performance | 5-7 Efficient Performance | 0-4 Improvements Possible | Unit Unoccupied

RTU-1	MON	TUES	WED	THUR	FRI	SAT	SUN
	8/16/2010	8/17/2010	8/18/2010	8/19/2010	8/20/2010	8/21/2010	8/22/2010
Static Pressure Performance	3	2	4	4	5	UNOCC	6
Supply Temperature Performance	4	5	3	3	5	UNOCC	5
Space Temperature Performance	5	7	3	6	3	UNOCC	0
Speed Drive Performance	2	4	2	3	4	UNOCC	10

Tozour-Trane
HIGH PERFORMANCE BUILDINGS FOR LIFE™

Sustainability Services
Weekly Rooftop Unit Performance Report



Unit performing in the Efficient to Optimuim range for the entire week.

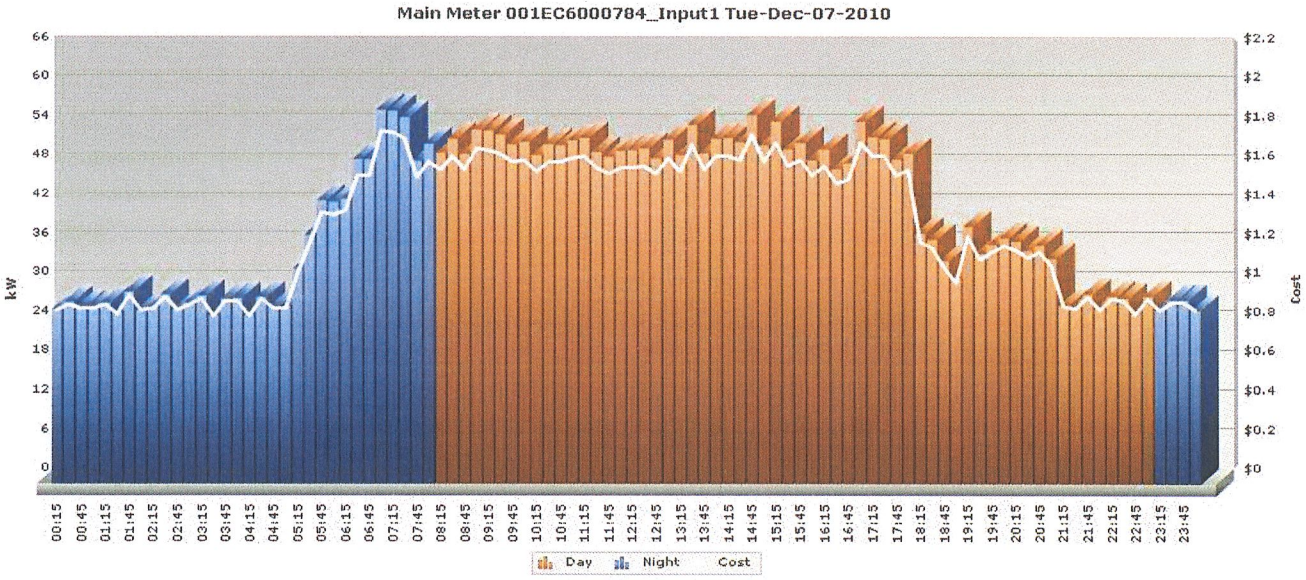
RTU-1	MON	TUES	WED	THUR	FRI	SAT	SUN
	9/13/2010	9/14/2010	9/15/2010	9/16/2010	9/17/2010	9/18/2010	9/19/2010
Overall Unit Performance	7	8	8	8	9	UNOCC	UNOCC

8-10 Optimum Performance	5-7 Efficient Performance	0-4 Improvements Possible	Unit Unoccupied

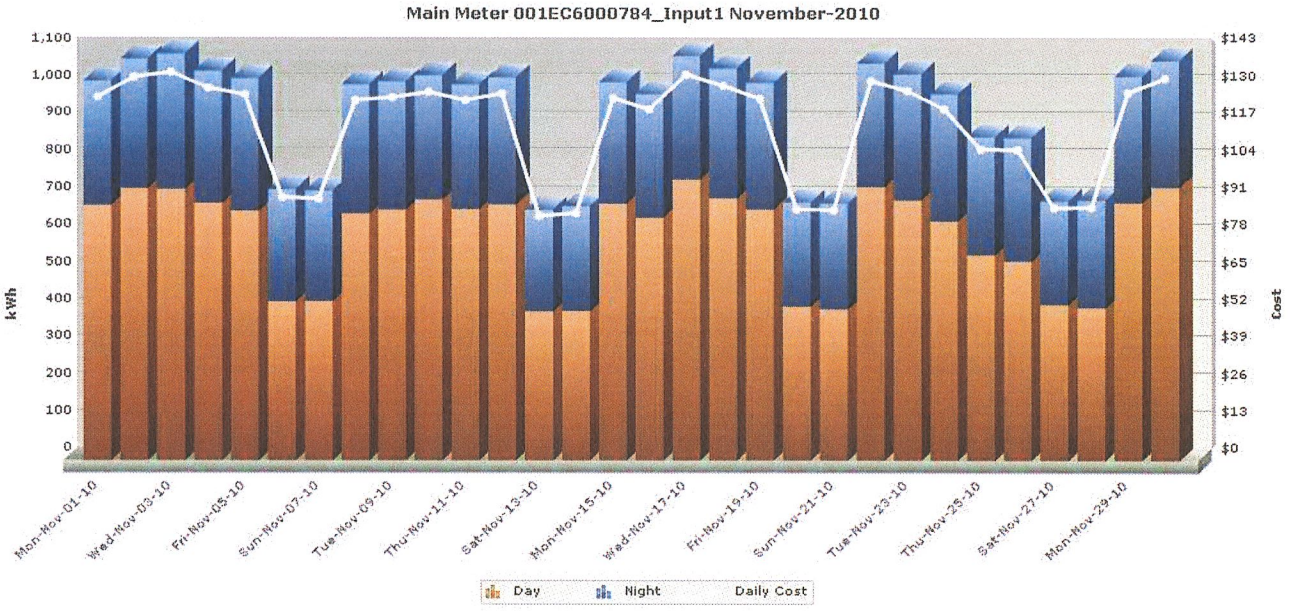
RTU-1	MON	TUES	WED	THUR	FRI	SAT	SUN
	9/13/2010	9/14/2010	9/15/2010	9/16/2010	9/17/2010	9/18/2010	9/19/2010
Static Pressure Performance	7	7	7	7	7	UNOCC	UNOCC
Supply Temperature Performance	8	8	7	7	9	UNOCC	UNOCC
Space Temperature Performance	10	8	9	9	9	UNOCC	UNOCC
Speed Drive Performance	9	10	10	10	10	UNOCC	UNOCC

Resample of RTU after Tozour Energy Systems Technician made field adjustments

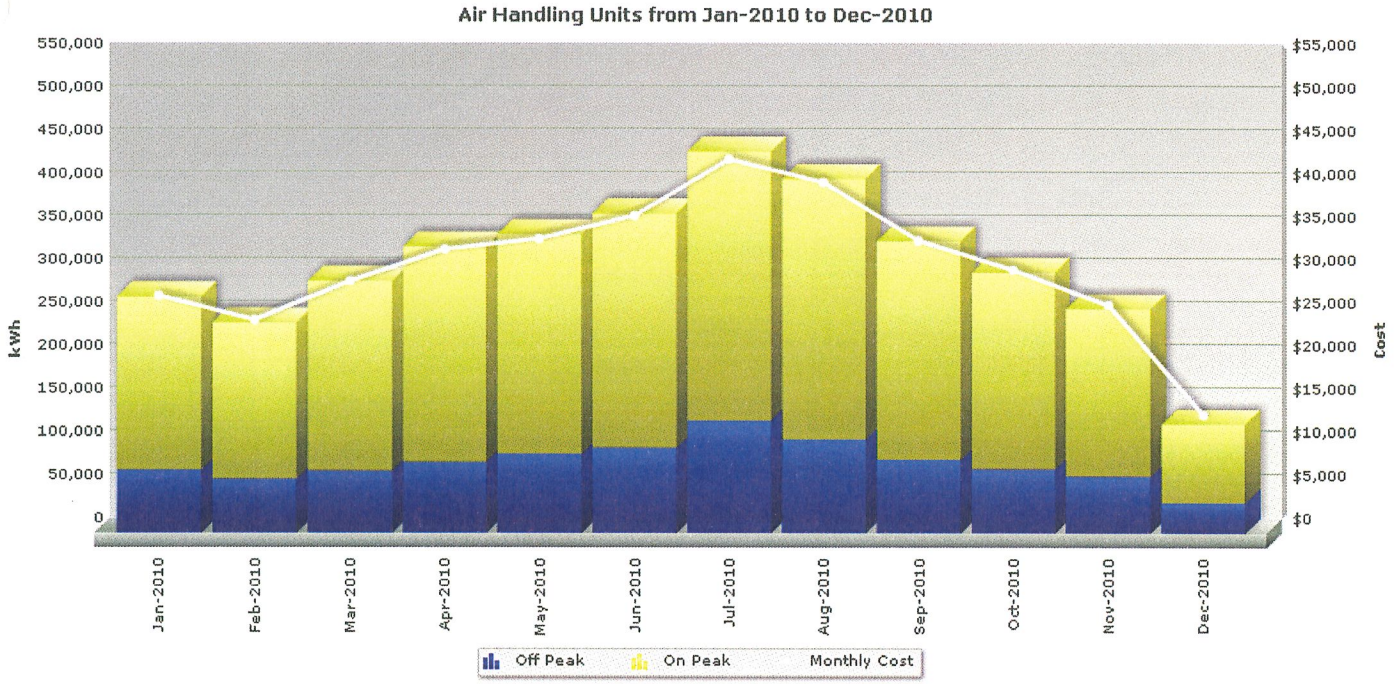
IV. Sustainability Services (Metering)



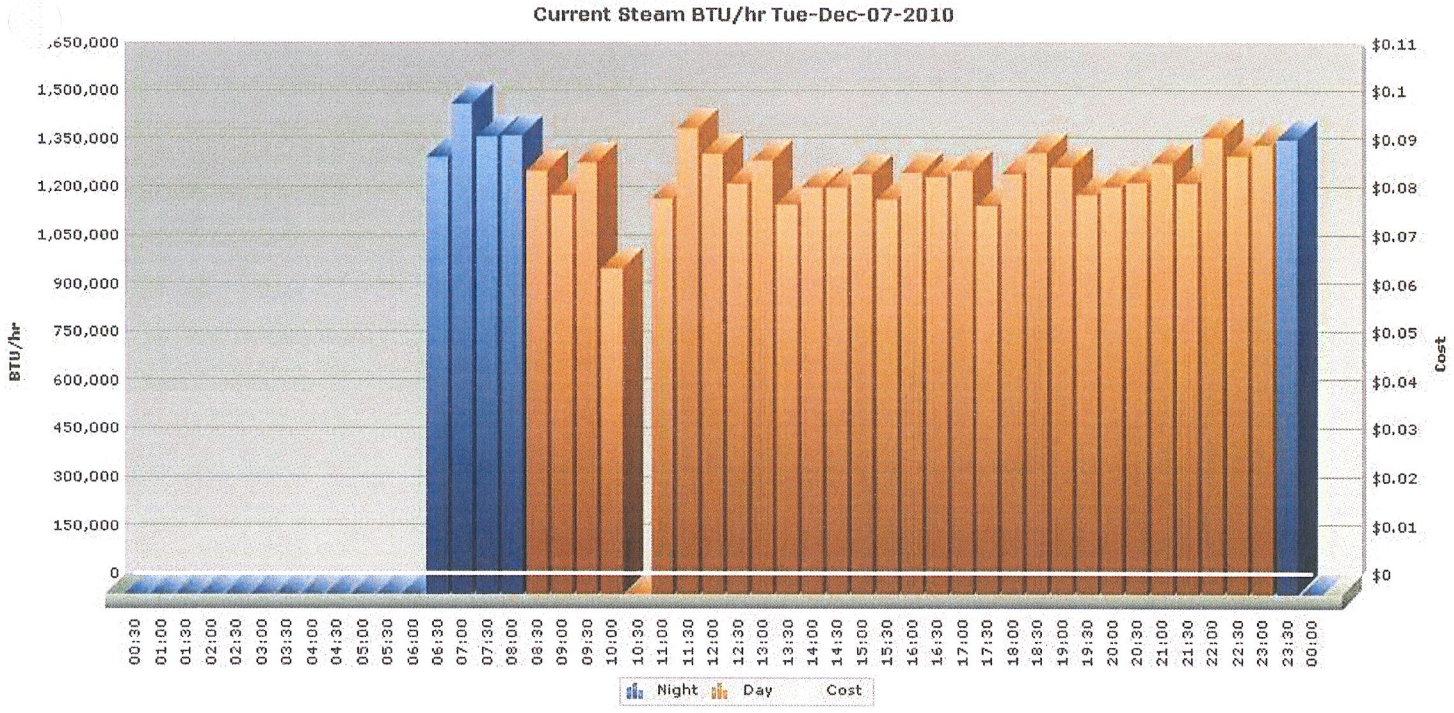
Metering and reports can be done on a daily basis to show peak KW and KWH usage



Peak and off peak monthly reports are available that show KWH and total cast



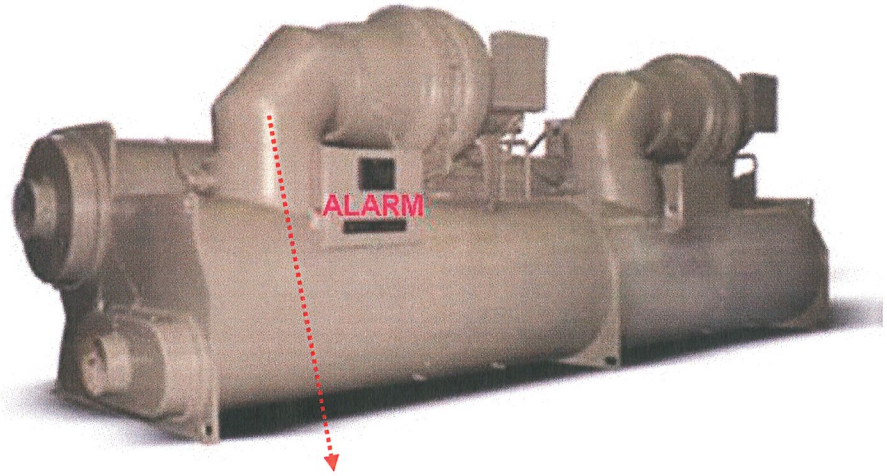
Annual reports showing total consumption as well as monthly totals



Metering of BTUs can be done by hour as well as daily and monthly

V. Sustainability Services (Remote Alarm Monitoring and analysis)

Even when equipment is running optimally a sudden an unforeseen problem can develop. Tozour Energy Systems monitors buildings and equipment for alarms on a 24/7/365 basis.



Tozour Energy Systems will monitor all alarms from the Tracer Summit System deemed critical by the customer on a 24/7/365 basis. Alarms can be designated to be at different levels of criticality allowing different levels and procedures of response. Example: A chiller failure could be an alarm warranting immediate notification and action. A single room temperature alarm may only require next day or e-mail notification. Tozour Energy Systems will tailor the response to fit the needs of the facility.

A Skilled Tozour Energy Systems Technician will receive the alarm, remotely connect to the system to verify, and troubleshoot the situation. The Tozour Energy Systems Technician will take all possible action to remotely reconfigure or reset the alarm returning the system to normal operation as quickly as possible. The customer can be notified immediately as a part of this process. If the situation can be efficiently and safely handled remotely, the customer can be notified after remote repairs have been made or the following day The Technician will also facilitate the dispatching -of a Technician for onsite repair if needed or work with the customer over the phone to resolve problems.



Financial Evaluator

The Energy Savings Improvement Program (ESIP) Project

	Manalapan Main & Police Headquarters	Include ? (Y/N)	Installed Cost	Electric Savings	Gas Savings	Demand Savings	Annual O&M Savings	Annual Cost Savings	Measure Life	Life Cycle Savings	IRR	Total Site Energy Saved	Total Source Energy Saved	% Of Source Energy Saved	Simple Payback without Incentive	P4P Incentive	Simple Payback with P4P Incentive
	Energy Conservation Measures (ECM)		$	kWh	DTh	kW	$	$	Years	$	%	MMBTU	MMBTU	%	Years	$	Years
1	Cooling Plant Upgrade	Y	$122,903	124,374	0	31	$0	$20,456	20	$181,429	15.8%	424	1,417	30.5%	6.0	$27,362	4.7
2	Heating Plant Upgrade	Y	$54,492	671	309	0	$0	$3,906	20	$3,623	3.7%	311	331	7.1%	14.0	$7,868	11.9
3	Lighting Upgrade	Y	$44,200	121,419	(97)	18	$0	$18,782	15	$180,022	42.3%	318	1,283	27.6%	2.4	$24,297	1.1
4	Controls Upgrade	Y	$168,763	60,706	216	5	$0	$12,636	15	-$17,916	1.5%	423	918	19.7%	13.4	$0	13.4
5	Air Handler Refurbishment	Y	$91,163	40,471	144	8	$0	$8,424	18	$24,696	6.0%	282	612	13.2%	10.8	$0	10.8
6	Facility Envelope Improvement	Y	$17,500	226	63	3	$0	$814	15	-$7,778	-4.2%	64	69	1.5%	21.5	$0	21.5
7	VAV Box Replacement	Y	$170,550	1,242	7	1	$0	$289	15	-$167,099	-29.1%	11	21	0.5%	590.0	$0	590.0
	TOTALS COST		$669,570														
	TOTAL PROJECT		$974,425	349,108	642	65.0	$0	$65,308		$196,976	1.6%	1,833	4,650	100.0%	14.9	$59,527	14.0

Solicit, evaluate project financing proposals	0.25%	$1,674
Design & engineering (100% specification)	7%	$46,870
Contingency	3%	$20,087
Permits	0%	$0
Performance Bond	1.25%	$8,370
Project Management	10%	$66,957
Retro-Commissioning	4%	$26,783
Legal review contract admin & procurement	0.25%	$1,674
Training	0.25%	$1,674
Subtotal		$843,658
Overhead	10%	$84,366
Subtotal + overhead		$928,024
Profit	5%	$46,401
Total		$974,425

36%
Total Savings

28%
Lighting Savings

294
CO_2 Tons

1,470
Trees Planted

51
Cars Removed

$59,527
Potential P4P Incentive

$65,308
1st Year Savings

Acceptable ESIP Project
Energy Savings Improvement Program (ESIP)

14.9
ESIP Self-Funded Years

$1,214,651
Cumulative 15 Year Savings

MONTHLY ENERGY CONSUMPTION

By Trane

------- Monthly Energy Consumption -------

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 1	**Manalapan Baseline**												
Electric													
On-Pk Cons. (kWh)	68,987	62,406	63,915	73,034	86,883	100,242	109,515	108,997	93,499	72,619	61,826	63,901	965,823
On-Pk Demand (kW)	101	101	86	158	173	179	186	185	175	149	86	86	186
Gas													
On-Pk Cons. (therms)	2,851	2,755	2,488	144	149	144	149	149	144	149	2,423	2,695	14,239
On-Pk Demand (therms/hr)	10	10	10	0	0	0	0	0	0	0	10	10	10

Energy Consumption

Building	157,241	Btu/(ft2-year)
Source	379,388	Btu/(ft2-year)
Floor Area	30,019	ft2

Environmental Impact Analysis

CO2	985,805 lbm/year
SO2	2,679 gm/year
NOX	1,382 gm/year

MONTHLY ENERGY CONSUMPTION

By Trane

------- Monthly Energy Consumption -------

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 2	**Plant Upgrade Standard Chiller**												
Electric													
On-Pk Cons. (kWh)	63,872	57,786	63,915	65,087	73,277	79,547	85,884	85,529	75,263	65,561	61,826	63,901	841,449
On-Pk Demand (kW)	86	86	86	126	135	145	156	153	136	117	86	86	156
Gas													
On-Pk Cons. (therms)	2,183	2,107	1,909	144	149	144	149	149	144	149	1,860	2,065	11,151
On-Pk Demand (therms/hr)	8	8	8	0	0	0	0	0	0	0	8	8	8

Energy Consumption		
Building	132,813	Btu/(ft2-year)
Source	326,133	Btu/(ft2-year)
Floor Area	30,019	ft2

Environmental Impact Analysis	
CO2	832,658 lbm/year
SO2	2,263 gm/year
NOX	1,167 gm/year

MONTHLY ENERGY CONSUMPTION

By Trane

------- Monthly Energy Consumption -------

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 3	**Lighting Replacement and Control**												
Electric													
On-Pk Cons. (kWh)	54,334	49,203	54,421	55,371	62,892	68,523	74,232	73,922	64,684	55,477	52,601	54,371	720,031
On-Pk Demand (kW)	73	73	73	109	118	128	137	138	119	104	73	73	138
Gas													
On-Pk Cons. (therms)	2,400	2,275	2,149	144	149	144	149	149	144	149	1,990	2,276	12,117
On-Pk Demand (therms/hr)	8	8	8	0	0	0	0	0	0	0	8	8	8

Energy Consumption

Building	122,227	Btu/(ft2-year)
Source	288,103	Btu/(ft2-year)
Floor Area	30,019	ft2

Environmental Impact Analysis

CO2	766,286 lbm/year
SO2	2,082 gm/year
NOX	1,074 gm/year

MONTHLY ENERGY CONSUMPTION

By Trane

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Energy Consumption -------												
Alternative: 4	**BAS Upgrade & AHU Refurbish**												
Electric													
On-Pk Cons. (kWh)	48,945	44,012	48,505	44,521	49,962	58,731	64,640	64,303	54,016	44,924	47,319	48,976	618,854
On-Pk Demand (kW)	73	73	73	87	104	115	125	125	110	83	73	73	125
Gas													
On-Pk Cons. (therms)	1,615	1,519	1,462	144	149	144	149	149	144	149	1,361	1,537	8,521
On-Pk Demand (therms/hr)	6	6	6	0	0	0	0	0	0	0	6	6	6

Energy Consumption

Building	98,747	Btu/(ft2-year)
Source	240,983	Btu/(ft2-year)
Floor Area	30,019	ft2

Environmental Impact Analysis

CO2	619,081 lbm/year
SO2	1,682 gm/year
NOX	868 gm/year

MONTHLY ENERGY CONSUMPTION

By Trane

------- Monthly Energy Consumption -------

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 1	**Manalapan Building Envelope Improvement**												
Electric													
On-Pk Cons. (kWh)	49,445	44,713	49,440	44,433	49,406	57,805	64,393	63,629	53,813	44,975	47,723	49,426	619,201
On-Pk Demand (kW)	73	73	73	85	102	112	122	121	108	81	73	73	122
Gas													
On-Pk Cons. (therms)	1,487	1,376	1,340	144	149	144	149	149	144	149	1,252	1,406	7,889
On-Pk Demand (therms/hr)	5	5	5	0	0	0	0	0	0	0	5	5	5

Energy Consumption

Building	96,681	Btu/(ft2-year)
Source	238,885	Btu/(ft2-year)
Floor Area	30,019	ft2

Environmental Impact Analysis

CO2	606,130 lbm/year
SO2	1,647 gm/year
NOX	850 gm/year

MONTHLY ENERGY CONSUMPTION

By Trane

------- Monthly Energy Consumption -------

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 2	**New VAV Boxes**												
Electric													
On-Pk Cons. (kWh)	49,435	44,686	49,378	44,274	49,316	57,614	64,025	63,243	53,328	44,940	47,732	49,414	617,386
On-Pk Demand (kW)	73	73	73	85	102	111	121	120	107	81	73	73	121
Gas													
On-Pk Cons. (therms)	1,469	1,358	1,329	144	149	144	149	149	144	149	1,244	1,392	7,820
On-Pk Demand (therms/hr)	5	5	5	0	0	0	0	0	0	0	5	5	5

Energy Consumption

Building	96,243	Btu/(ft2-year)
Source	238,022	Btu/(ft2-year)
Floor Area	30,019	ft2

Environmental Impact Analysis

CO2	603,386 lbm/year
SO2	1,640 gm/year
NOX	846 gm/year

MONTHLY UTILITY COSTS

By Trane

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Utility Costs -------								
Baseline													
Electric													
On-Pk Cons. ($)	11,348	10,266	10,514	12,014	14,292	16,490	18,015	17,930	15,381	11,946	10,170	10,512	158,878
Gas													
On-Pk Cons. ($)	3,504	3,386	3,058	177	183	177	183	183	177	183	2,979	3,312	17,502
Monthly Total ($):	14,853	13,652	13,572	12,191	14,475	16,667	18,198	18,113	15,558	12,129	13,149	13,824	176,380

Building Area = 30,019 ft²
Utility Cost Per Area = 5.88 $/ft²

Cooling & Heating Plant													
Electric													
On-Pk Cons. ($)	10,507	9,506	10,514	10,707	12,054	13,086	14,128	14,070	12,381	10,785	10,170	10,512	138,418
Gas													
On-Pk Cons. ($)	2,683	2,590	2,347	177	183	177	183	183	177	183	2,286	2,538	13,706
Monthly Total ($):	13,190	12,096	12,861	10,884	12,237	13,263	14,311	14,252	12,558	10,968	12,456	13,050	152,124

Building Area = 30,019 ft²
Utility Cost Per Area = 5.07 $/ft²

MONTHLY UTILITY COSTS

By Trane

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Utility Costs -------								
Lighting													
Electric													
On-Pk Cons. ($)	8,938	8,094	8,952	9,109	10,346	11,272	12,211	12,160	10,640	9,126	8,653	8,944	118,445
Gas													
On-Pk Cons. ($)	2,950	2,797	2,641	177	183	177	183	183	177	183	2,446	2,797	14,893
Monthly Total ($):	11,888	10,890	11,593	9,286	10,529	11,449	12,394	12,343	10,817	9,309	11,098	11,741	133,338

Building Area = 30,019 ft²
Utility Cost Per Area = 4.44 $/ft²

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Controls & AHU Refurbish													
Electric													
On-Pk Cons. ($)	8,052	7,240	7,979	7,324	8,219	9,661	10,633	10,578	8,886	7,390	7,784	8,057	101,801
Gas													
On-Pk Cons. ($)	1,985	1,867	1,797	177	183	177	183	183	177	183	1,673	1,890	10,474
Monthly Total ($):	10,037	9,107	9,776	7,501	8,402	9,838	10,816	10,761	9,063	7,573	9,457	9,946	112,276

Building Area = 30,019 ft²
Utility Cost Per Area = 3.74 $/ft²

MONTHLY UTILITY COSTS

By Trane

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Utility Costs -------								
Building Envelope													
Electric													
On-Pk Cons. ($)	8,134	7,355	8,133	7,309	8,127	9,509	10,593	10,467	8,852	7,398	7,850	8,130	101,859
Gas													
On-Pk Cons. ($)	1,828	1,692	1,648	177	183	177	183	183	177	183	1,539	1,728	9,697
Monthly Total ($):	9,962	9,047	9,781	7,486	8,310	9,686	10,776	10,650	9,029	7,581	9,389	9,858	111,556

Building Area = 30,019 ft²

Utility Cost Per Area = 3.72 $/ft²

VAV Box Replacement													
Electric													
On-Pk Cons. ($)	8,132	7,351	8,123	7,283	8,113	9,477	10,532	10,404	8,772	7,393	7,852	8,129	101,560
Gas													
On-Pk Cons. ($)	1,806	1,669	1,634	177	183	177	183	183	177	183	1,529	1,711	9,612
Monthly Total ($):	9,938	9,020	9,757	7,460	8,295	9,654	10,715	10,586	8,949	7,576	9,381	9,840	111,172

Building Area = 30,019 ft²

Utility Cost Per Area = 3.70 $/ft²

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 1 Manalapan Baseline

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Lights													
Electric (kWh)	22,457.2	20,283.9	22,457.2	21,732.8	22,457.2	21,732.8	22,457.2	22,457.2	21,732.8	22,457.2	21,732.8	22,457.2	264,415.3
Peak (kW)	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2
Misc. Ld													
Electric (kWh)	3,821.1	3,451.3	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	44,990.8
Peak (kW)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Cooling Coil Condensate													
Recoverable Water (1000gal)	0.0	0.0	0.0	0.1	0.7	3.4	4.2	4.9	2.5	0.1	0.0	0.0	15.7
Peak (1000gal/Hr)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bsu 1: Manalapan Dom HW & Cooking													
Gas (therms)	148.8	134.4	148.8	144.0	148.8	144.0	148.8	148.8	144.0	148.8	144.0	148.8	1,752.0
Peak (therms/Hr)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Bsu 2: Electric Heaters													
Electric (kWh)	5,115.0	4,620.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9,735.0
Peak (kW)	15.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=81.14 tons]													
Air-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=60 tons / 95.89 kW] (Cooling Equipment)													
Electric (kWh)	0.0	0.0	0.0	10,037.5	18,397.9	29,897.0	36,521.0	36,047.3	23,522.9	8,224.5	0.0	0.0	162,648.1
Peak (kW)	0.0	0.0	0.0	60.9	75.2	81.0	89.0	87.1	79.6	53.8	0.0	0.0	89.0
MZ packaged rooftop cond fan [Design Heat Rejection/F.L.Rate=87.27 tons / 7.33 kW]													
Electric (kWh)	0.0	0.0	0.0	1,024.4	1,827.6	2,860.5	3,321.0	3,303.3	2,293.3	843.5	0.0	0.0	15,473.5
Peak (kW)	0.0	0.0	0.0	6.0	6.8	7.0	7.2	7.1	6.9	5.3	0.0	0.0	7.2
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	4,921.6	7,859.7	10,738.1	11,096.1	11,096.1	10,738.1	4,623.4	0.0	0.0	61,073.0
Peak (kW)	0.0	0.0	0.0	14.9	14.9	14.9	14.9	14.9	14.9	14.9	0.0	0.0	14.9
Cntl panel & interlocks - 0.1 KW (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	33.0	52.7	72.0	74.4	74.4	72.0	31.0	0.0	0.0	409.5
Peak (kW)	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=669.5 mbh]													

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 1 Manalapan Baseline

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=669.5 mbh]													
Boiler - 001 [Nominal Capacity/F.L.Rate=1,200 mbh / 17.14 Therms] (Heating Equipment)													
Gas (therms)	2,702.0	2,620.5	2,339.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,279.4	2,545.7	12,486.6
Peak (therms/Hr)	10.3	10.3	10.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.2	10.2	10.3
Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	3,698.7	3,340.8	3,698.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,579.4	3,698.7	18,016.2
Peak (kW)	5.0	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0	5.0
Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	892.8	806.4	892.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	864.0	892.8	4,348.8
Peak (kW)	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	1.2
Cntl panel & interlocks - 0.5 KW (Misc Accessory Equipment)													
Electric (kWh)	372.0	336.0	372.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.0	372.0	1,812.0
Peak (kW)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5
Sys 1: AHU-5													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=4,341 cfm / 7.46 kW] (Main Clg Fan)													
Electric (kWh)	5,346.5	4,881.0	5,327.3	5,166.2	5,215.4	4,981.0	5,115.9	5,101.7	5,037.1	5,330.1	5,167.5	5,356.1	62,025.7
Peak (kW)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
FC Centrifugal const vol [DsnAirflow/F.L.Rate=4,606 cfm / 2.24 kW] (Main Return Fan)													
Electric (kWh)	1,592.4	1,455.9	1,617.3	1,558.1	1,624.1	1,563.1	1,612.0	1,605.4	1,557.9	1,595.8	1,549.4	1,600.1	18,931.5
Peak (kW)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Sys 2: AHU-2													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,898 cfm / 5.59 kW] (Main Clg Fan)													
Electric (kWh)	4,161.0	3,758.3	4,161.0	4,026.8	4,161.0	4,026.8	4,161.0	4,161.0	4,026.8	4,161.0	4,026.8	4,161.0	48,992.6
Peak (kW)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,963 cfm / 2.24 kW] (Main Return Fan)													
Electric (kWh)	1,622.8	1,475.9	1,637.2	1,580.3	1,641.1	1,583.2	1,634.1	1,630.3	1,580.2	1,624.7	1,575.2	1,627.2	19,211.9
Peak (kW)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Sys 3: AHU-3													

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 1 Manalapan Baseline

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Sys 3: AHU-3													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=10,589 cfm / 3.73 kW] (Main Clg Fan)													
Electric (kWh)	2,774.0	2,505.6	2,774.0	2,659.1	2,732.1	2,633.4	2,724.9	2,719.4	2,648.9	2,769.7	2,684.5	2,774.0	32,399.6
Peak (kW)	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
FC Centrifugal const vol [DsnAirflow/F.L.Rate=10,699 cfm / 0.75 kW] (Main Return Fan)													
Electric (kWh)	550.5	498.3	552.0	533.8	552.4	534.1	551.7	551.3	533.8	550.7	533.3	551.0	6,492.7
Peak (kW)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Sys 4: AHU-1													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=7,202 cfm / 11.19 kW] (Main Clg Fan)													
Electric (kWh)	8,322.0	7,516.7	8,322.0	8,053.6	8,322.0	8,053.6	8,322.0	8,322.0	8,053.6	8,322.0	8,053.6	8,322.0	97,985.3
Peak (kW)	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
FC Centrifugal const vol [DsnAirflow/F.L.Rate=7,449 cfm / 1.49 kW] (Main Return Fan)													
Electric (kWh)	1,082.0	984.0	1,091.5	1,053.6	1,094.2	1,055.5	1,089.5	1,087.0	1,053.6	1,083.3	1,050.3	1,085.0	12,809.4
Peak (kW)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sys 5: AHU-4													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=6,654 cfm / 7.46 kW] (Main Clg Fan)													
Electric (kWh)	5,548.0	5,011.1	5,548.0	5,369.1	5,479.1	5,224.1	5,373.0	5,382.3	5,364.2	5,548.0	5,369.1	5,548.0	64,764.0
Peak (kW)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
FC Centrifugal const vol [DsnAirflow/F.L.Rate=6,836 cfm / 2.24 kW] (Main Return Fan)													
Electric (kWh)	1,631.1	1,481.3	1,642.6	1,586.3	1,645.7	1,588.7	1,640.1	1,637.1	1,586.2	1,632.6	1,582.3	1,634.6	19,288.7
Peak (kW)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 2 Plant Upgrade Standard Chiller

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Lights													
Electric (kWh)	22,457.2	20,283.9	22,457.2	21,732.8	22,457.2	21,732.8	22,457.2	22,457.2	21,732.8	22,457.2	21,732.8	22,457.2	264,415.3
Peak (kW)	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2
Misc. Ld													
Electric (kWh)	3,821.1	3,451.3	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	44,990.8
Peak (kW)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Cooling Coil Condensate													
Recoverable Water (1000gal)	0.0	0.0	0.0	0.1	0.7	3.4	4.2	4.9	2.5	0.1	0.0	0.0	15.7
Peak (1000gal/Hr)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bsu 1: Manalapan Dom HW & Cooking													
Gas (therms)	148.8	134.4	148.8	144.0	148.8	144.0	148.8	148.8	144.0	148.8	144.0	148.8	1,752.0
Peak (therms/Hr)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=81.14 tons]													
Air-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=120 tons / 136.8 kW] (Cooling Equipment)													
Electric (kWh)	0.0	0.0	0.0	6,324.2	11,486.6	18,235.4	22,130.7	21,819.3	14,516.8	5,184.7	0.0	0.0	99,697.7
Peak (kW)	0.0	0.0	0.0	38.7	46.7	56.1	66.7	65.6	49.7	33.6	0.0	0.0	66.7
MZ packaged rooftop cond fan [Design Heat Rejection/F.L.Rate=158.9 tons / 13.35 kW]													
Electric (kWh)	0.0	0.0	0.0	935.7	1,662.5	2,581.9	2,977.2	2,963.4	2,078.1	770.8	0.0	0.0	13,969.6
Peak (kW)	0.0	0.0	0.0	5.5	6.3	7.0	7.6	7.6	6.3	4.8	0.0	0.0	7.6
Var vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	480.0	855.2	1,335.9	1,529.9	1,527.0	1,075.4	399.4	0.0	0.0	7,202.8
Peak (kW)	0.0	0.0	0.0	3.0	3.6	4.3	4.8	4.7	3.6	2.5	0.0	0.0	4.8
Cntl panel & interlocks - 1 KW (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	330.0	527.0	720.0	744.0	744.0	720.0	310.0	0.0	0.0	4,095.0
Peak (kW)	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=669.5 mbh]													
Boiler - 001 [Nominal Capacity/F.L.Rate=1,200 mbh / 12.90 Therms] (Heating Equipment)													
Gas (therms)	2,033.8	1,972.4	1,760.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,715.7	1,916.1	9,398.5
Peak (therms/Hr)	7.7	7.7	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	7.7	7.7

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 2 Plant Upgrade Standard Chiller

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=669.5 mbh]													
Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	3,698.7	3,340.8	3,698.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,579.4	3,698.7	18,016.2
Peak (kW)	5.0	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0	5.0
Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	892.8	806.4	892.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	864.0	892.8	4,348.8
Peak (kW)	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	1.2
Cntl panel & interlocks - 0.5 KW (Misc Accessory Equipment)													
Electric (kWh)	372.0	336.0	372.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.0	372.0	1,812.0
Peak (kW)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5
Sys 1: AHU-5													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=4,341 cfm / 7.46 kW] (Main Clg Fan)													
Electric (kWh)	5,346.5	4,881.0	5,327.3	5,166.2	5,215.4	4,981.0	5,115.9	5,101.7	5,037.1	5,330.1	5,167.5	5,356.1	62,025.7
Peak (kW)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
FC Centrifugal const vol [DsnAirflow/F.L.Rate=4,606 cfm / 2.24 kW] (Main Return Fan)													
Electric (kWh)	1,592.4	1,455.9	1,617.3	1,558.1	1,624.1	1,563.1	1,612.0	1,605.4	1,557.9	1,595.8	1,549.4	1,600.1	18,931.5
Peak (kW)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Sys 2: AHU-2													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,898 cfm / 5.59 kW] (Main Clg Fan)													
Electric (kWh)	4,161.0	3,758.3	4,161.0	4,026.8	4,161.0	4,026.8	4,161.0	4,161.0	4,026.8	4,161.0	4,026.8	4,161.0	48,992.6
Peak (kW)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,963 cfm / 2.24 kW] (Main Return Fan)													
Electric (kWh)	1,622.8	1,475.9	1,637.2	1,580.3	1,641.1	1,583.2	1,634.1	1,630.3	1,580.2	1,624.7	1,575.2	1,627.2	19,211.9
Peak (kW)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Sys 3: AHU-3													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=10,589 cfm / 3.73 kW] (Main Clg Fan)													
Electric (kWh)	2,774.0	2,505.6	2,774.0	2,659.1	2,732.1	2,633.4	2,724.9	2,719.4	2,648.9	2,769.7	2,684.5	2,774.0	32,399.6
Peak (kW)	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 2 Plant Upgrade Standard Chiller

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Sys 3: AHU-3													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=10,699 cfm / 0.75 kW] (Main Return Fan)													
Electric (kWh)	550.5	498.3	552.0	533.8	552.4	534.1	551.7	551.3	533.8	550.7	533.3	551.0	6,492.7
Peak (kW)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Sys 4: AHU-1													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=7,202 cfm / 11.19 kW] (Main Clg Fan)													
Electric (kWh)	8,322.0	7,516.7	8,322.0	8,053.6	8,322.0	8,053.6	8,322.0	8,322.0	8,053.6	8,322.0	8,053.6	8,322.0	97,985.3
Peak (kW)	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
FC Centrifugal const vol [DsnAirflow/F.L.Rate=7,449 cfm / 1.49 kW] (Main Return Fan)													
Electric (kWh)	1,082.0	984.0	1,091.5	1,053.6	1,094.2	1,055.5	1,089.5	1,087.0	1,053.6	1,083.3	1,050.3	1,085.0	12,809.4
Peak (kW)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sys 5: AHU-4													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=6,654 cfm / 7.46 kW] (Main Clg Fan)													
Electric (kWh)	5,548.0	5,011.1	5,548.0	5,369.1	5,479.1	5,224.1	5,373.0	5,382.3	5,364.2	5,548.0	5,369.1	5,548.0	64,764.0
Peak (kW)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
FC Centrifugal const vol [DsnAirflow/F.L.Rate=6,836 cfm / 2.24 kW] (Main Return Fan)													
Electric (kWh)	1,631.1	1,481.3	1,642.6	1,586.3	1,645.7	1,588.7	1,640.1	1,637.1	1,586.2	1,632.6	1,582.3	1,634.6	19,288.7
Peak (kW)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 3 Lighting Replacement and Control

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Lights													
Electric (kWh)	12,842.4	11,599.6	12,842.4	12,428.1	12,842.4	12,428.1	12,842.4	12,842.4	12,428.1	12,842.4	12,428.1	12,842.4	151,208.6
Peak (kW)	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3
Misc. Ld													
Electric (kWh)	3,821.1	3,451.3	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	44,990.8
Peak (kW)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Cooling Coil Condensate													
Recoverable Water (1000gal)	0.0	0.0	0.0	0.1	0.8	3.4	4.2	4.9	2.6	0.1	0.0	0.0	16.0
Peak (1000gal/Hr)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bsu 1: Manalapan Dom HW & Cooking													
Gas (therms)	148.8	134.4	148.8	144.0	148.8	144.0	148.8	148.8	144.0	148.8	144.0	148.8	1,752.0
Peak (therms/Hr)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=76.89 tons]													
Air-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=120 tons / 136.8 kW] (Cooling Equipment)													
Electric (kWh)	0.0	0.0	0.0	5,869.0	10,635.1	16,659.1	20,273.5	20,042.5	13,344.6	4,725.2	0.0	0.0	91,549.0
Peak (kW)	0.0	0.0	0.0	35.8	43.4	52.3	62.2	58.8	46.3	31.1	0.0	0.0	62.2
MZ packaged rooftop cond fan [Design Heat Rejection/F.L.Rate=158.9 tons / 13.35 kW]													
Electric (kWh)	0.0	0.0	0.0	871.9	1,548.1	2,368.7	2,739.1	2,733.7	1,918.5	704.9	0.0	0.0	12,884.8
Peak (kW)	0.0	0.0	0.0	5.1	5.9	6.6	7.2	7.1	5.9	4.5	0.0	0.0	7.2
Var vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	452.4	795.1	1,219.8	1,395.8	1,397.2	991.1	369.6	0.0	0.0	6,621.1
Peak (kW)	0.0	0.0	0.0	2.7	3.2	3.9	4.3	4.3	3.3	2.3	0.0	0.0	4.3
Cntl panel & interlocks - 1 KW (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	390.0	558.0	720.0	744.0	744.0	720.0	341.0	0.0	0.0	4,217.0
Peak (kW)	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=644.9 mbh]													
Boiler - 001 [Nominal Capacity/F.L.Rate=1,200 mbh / 12.90 Therms] (Heating Equipment)													
Gas (therms)	2,251.2	2,140.8	1,999.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,845.6	2,127.1	10,364.6
Peak (therms/Hr)	7.7	7.7	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	7.7	7.7

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 3 Lighting Replacement and Control

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=644.9 mbh]													
Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	3,698.7	3,340.8	3,698.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,579.4	3,698.7	18,016.2
Peak (kW)	5.0	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0	5.0
Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	892.8	806.4	892.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	864.0	892.8	4,348.8
Peak (kW)	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	1.2
Cntl panel & interlocks - 0.5 KW (Misc Accessory Equipment)													
Electric (kWh)	372.0	336.0	372.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.0	372.0	1,812.0
Peak (kW)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5
Sys 1: AHU-5													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=3,648 cfm / 7.46 kW] (Main Clg Fan)													
Electric (kWh)	5,445.2	4,996.5	5,463.1	5,248.5	5,373.5	5,119.5	5,270.0	5,230.4	5,181.2	5,401.5	5,266.2	5,460.6	63,456.0
Peak (kW)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
FC Centrifugal const vol [DsnAirflow/F.L.Rate=3,914 cfm / 2.24 kW] (Main Return Fan)													
Electric (kWh)	1,579.7	1,447.5	1,609.0	1,548.8	1,617.0	1,554.7	1,602.7	1,594.9	1,548.6	1,583.7	1,538.5	1,588.8	18,813.8
Peak (kW)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Sys 2: AHU-2													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,725 cfm / 5.59 kW] (Main Clg Fan)													
Electric (kWh)	4,161.0	3,758.3	4,161.0	4,026.8	4,161.0	4,026.8	4,161.0	4,161.0	4,026.8	4,161.0	4,026.8	4,161.0	48,992.6
Peak (kW)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,790 cfm / 2.24 kW] (Main Return Fan)													
Electric (kWh)	1,618.7	1,473.2	1,634.5	1,577.3	1,638.9	1,580.5	1,631.1	1,627.0	1,577.2	1,620.9	1,571.8	1,623.6	19,174.8
Peak (kW)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Sys 3: AHU-3													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=10,210 cfm / 3.73 kW] (Main Clg Fan)													
Electric (kWh)	2,774.0	2,505.6	2,774.0	2,668.0	2,742.8	2,645.7	2,734.8	2,732.5	2,657.5	2,774.0	2,684.5	2,774.0	32,467.5
Peak (kW)	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 3 Lighting Replacement and Control

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Sys 3: AHU-3													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=10,320 cfm / 0.75 kW] (Main Return Fan)													
Electric (kWh)	550.4	498.2	551.9	533.7	552.3	534.0	551.6	551.2	533.7	550.6	533.1	550.8	6,491.3
Peak (kW)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Sys 4: AHU-1													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=6,522 cfm / 11.19 kW] (Main Clg Fan)													
Electric (kWh)	8,322.0	7,516.7	8,322.0	8,053.6	8,322.0	8,053.6	8,322.0	8,322.0	8,053.6	8,322.0	8,053.6	8,322.0	97,985.3
Peak (kW)	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
FC Centrifugal const vol [DsnAirflow/F.L.Rate=6,769 cfm / 1.49 kW] (Main Return Fan)													
Electric (kWh)	1,079.2	982.2	1,089.7	1,051.6	1,092.6	1,053.7	1,087.5	1,084.7	1,051.5	1,080.7	1,047.9	1,082.5	12,783.7
Peak (kW)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sys 5: AHU-4													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=6,178 cfm / 7.46 kW] (Main Clg Fan)													
Electric (kWh)	5,548.0	5,011.1	5,548.0	5,369.1	5,548.0	5,274.1	5,417.1	5,402.9	5,369.1	5,548.0	5,369.1	5,548.0	64,952.5
Peak (kW)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
FC Centrifugal const vol [DsnAirflow/F.L.Rate=6,360 cfm / 2.24 kW] (Main Return Fan)													
Electric (kWh)	1,628.6	1,479.7	1,640.9	1,584.5	1,644.4	1,587.0	1,638.3	1,635.0	1,584.4	1,630.3	1,580.2	1,632.4	19,265.6
Peak (kW)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 4 BAS Upgrade & AHU Refurbish

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Lights													
Electric (kWh)	12,842.4	11,599.6	12,842.4	12,428.1	12,842.4	12,428.1	12,842.4	12,842.4	12,428.1	12,842.4	12,428.1	12,842.4	151,208.6
Peak (kW)	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3
Misc. Ld													
Electric (kWh)	3,821.1	3,451.3	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	44,990.8
Peak (kW)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Cooling Coil Condensate													
Recoverable Water (1000gal)	0.0	0.0	0.0	0.0	0.8	3.8	3.7	4.4	2.8	0.1	0.0	0.0	15.6
Peak (1000gal/Hr)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bsu 1: Manalapan Dom HW & Cooking													
Gas (therms)	148.8	134.4	148.8	144.0	148.8	144.0	148.8	148.8	144.0	148.8	144.0	148.8	1,752.0
Peak (therms/Hr)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=76.89 tons]													
Air-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=120 tons / 136.8 kW] (Cooling Equipment)													
Electric (kWh)	0.0	0.0	0.0	1,415.5	4,708.8	13,533.3	17,772.8	17,376.2	9,758.0	865.6	0.0	0.0	65,430.2
Peak (kW)	0.0	0.0	0.0	20.5	42.4	54.0	64.9	62.3	47.9	20.3	0.0	0.0	64.9
Condenser fan for Centrifugal [Design Heat Rejection/F.L.Rate=158.9 tons / 15.10 kW]													
Electric (kWh)	0.0	0.0	0.0	239.9	784.4	2,182.3	2,727.4	2,689.1	1,590.0	146.9	0.0	0.0	10,360.0
Peak (kW)	0.0	0.0	0.0	3.2	6.4	7.6	8.3	8.2	6.9	2.6	0.0	0.0	8.3
Manalapan Pumps with Controls (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	4.0	31.6	185.3	258.9	262.8	104.4	1.8	0.0	0.0	848.8
Peak (kW)	0.0	0.0	0.0	0.2	1.4	2.2	2.6	2.5	1.6	0.1	0.0	0.0	2.6
Cntl panel & interlocks - 1 KW (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	342.0	514.0	720.0	744.0	744.0	700.0	319.0	0.0	0.0	4,083.0
Peak (kW)	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=644.9 mbh]													
Boiler - 001 [Nominal Capacity/F.L.Rate=1,200 mbh / 12.90 Therms] (Heating Equipment)													
Gas (therms)	1,466.1	1,384.3	1,312.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,217.4	1,388.5	6,769.3
Peak (therms/Hr)	5.6	5.6	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	5.5	5.6

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 4 BAS Upgrade & AHU Refurbish

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=644.9 mbh]													
Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	3,698.7	3,340.8	3,698.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,579.4	3,698.7	18,016.2
Peak (kW)	5.0	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0	5.0
Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	892.8	806.4	892.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	864.0	892.8	4,348.8
Peak (kW)	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	1.2
Cntl panel & interlocks - 0.5 KW (Misc Accessory Equipment)													
Electric (kWh)	372.0	336.0	372.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.0	372.0	1,812.0
Peak (kW)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5
Sys 1: AHU-5													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=3,648 cfm / 7.08 kW] (Main Clg Fan)													
Electric (kWh)	4,871.5	4,007.2	4,283.6	4,703.8	4,818.0	4,448.1	4,552.5	4,453.9	4,573.7	4,878.6	4,707.7	4,913.5	55,212.2
Peak (kW)	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=3,914 cfm / 3.54 kW] (Main Return Fan)													
Electric (kWh)	2,310.4	2,161.8	2,417.3	2,308.1	2,446.0	2,317.7	2,390.2	2,355.1	2,301.0	2,325.0	2,271.4	2,342.6	27,946.5
Peak (kW)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Sys 2: AHU-2													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,725 cfm / 5.31 kW] (Main Clg Fan)													
Electric (kWh)	1,450.5	1,322.7	1,588.6	1,271.9	1,519.6	1,519.6	1,392.0	1,588.6	1,381.4	1,429.2	1,450.5	1,381.4	17,296.0
Peak (kW)	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,790 cfm / 2.13 kW] (Main Return Fan)													
Electric (kWh)	573.4	533.4	641.7	514.4	619.2	612.9	562.7	634.5	556.5	567.3	578.0	551.5	6,945.3
Peak (kW)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Sys 3: AHU-3													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=10,210 cfm / 3.54 kW] (Main Clg Fan)													
Electric (kWh)	2,361.9	2,133.6	2,309.5	2,428.3	2,529.0	2,447.6	2,523.2	2,515.1	2,377.5	2,311.7	2,235.2	2,361.2	28,533.7
Peak (kW)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 4 BAS Upgrade & AHU Refurbish

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Sys 3: AHU-3													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=10,320 cfm / 0.67 kW] (Main Return Fan)													
Electric (kWh)	490.5	445.6	494.1	477.1	494.8	476.8	493.2	491.9	476.5	491.0	475.9	491.6	5,798.9
Peak (kW)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Sys 4: AHU-1													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=6,522 cfm / 10.63 kW] (Main Clg Fan)													
Electric (kWh)	7,931.2	7,163.7	7,931.2	7,675.4	7,566.3	7,207.7	7,355.8	7,407.1	7,050.5	7,931.2	7,675.4	7,931.2	90,826.8
Peak (kW)	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=6,769 cfm / 1.42 kW] (Main Return Fan)													
Electric (kWh)	984.3	906.4	1,009.0	969.5	1,016.2	974.5	1,003.8	997.2	969.3	987.7	960.7	991.9	11,770.5
Peak (kW)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Sys 5: AHU-4													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=6,178 cfm / 7.08 kW] (Main Clg Fan)													
Electric (kWh)	4,845.6	4,428.8	4,674.1	4,573.9	4,713.6	4,507.4	4,682.8	4,617.0	4,580.0	4,502.4	4,574.1	4,876.2	55,576.0
Peak (kW)	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=6,360 cfm / 2.13 kW] (Main Return Fan)													
Electric (kWh)	1,499.2	1,374.9	1,528.7	1,471.0	1,537.2	1,471.6	1,517.3	1,507.1	1,470.9	1,503.2	1,460.6	1,508.3	17,849.9
Peak (kW)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 1 Manalapan Building Envelope Improvement

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Lights													
Electric (kWh)	12,842.4	11,599.6	12,842.4	12,428.1	12,842.4	12,428.1	12,842.4	12,842.4	12,428.1	12,842.4	12,428.1	12,842.4	151,208.6
Peak (kW)	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3
Misc. Ld													
Electric (kWh)	3,821.1	3,451.3	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	44,990.8
Peak (kW)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Cooling Coil Condensate													
Recoverable Water (1000gal)	0.0	0.0	0.0	0.0	0.4	3.2	3.0	3.5	2.3	0.0	0.0	0.0	12.4
Peak (1000gal/Hr)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bsu 1: Manalapan Dom HW & Cooking													
Gas (therms)	148.8	134.4	148.8	144.0	148.8	144.0	148.8	148.8	144.0	148.8	144.0	148.8	1,752.0
Peak (therms/Hr)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=74.92 tons]													
Air-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=120 tons / 136.8 kW] (Cooling Equipment)													
Electric (kWh)	0.0	0.0	0.0	1,156.3	4,216.9	12,551.3	17,221.8	16,619.1	9,174.2	639.7	0.0	0.0	61,579.1
Peak (kW)	0.0	0.0	0.0	20.5	40.7	51.7	62.0	59.2	46.2	20.3	0.0	0.0	62.0
Condenser fan for Centrifugal [Design Heat Rejection/F.L.Rate=158.9 tons / 15.10 kW]													
Electric (kWh)	0.0	0.0	0.0	196.0	701.8	2,021.0	2,644.1	2,576.9	1,494.0	108.6	0.0	0.0	9,742.4
Peak (kW)	0.0	0.0	0.0	3.3	6.2	7.4	8.0	7.8	6.8	2.4	0.0	0.0	8.0
Manalapan Pumps with Controls (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	3.0	26.0	168.3	238.2	232.6	92.4	1.2	0.0	0.0	761.7
Peak (kW)	0.0	0.0	0.0	0.2	1.2	1.9	2.3	2.2	1.5	0.1	0.0	0.0	2.3
Cntl panel & interlocks - 1 KW (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	276.0	483.0	702.0	744.0	744.0	660.0	235.0	0.0	0.0	3,844.0
Peak (kW)	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=578.2 mbh]													
Boiler - 001 [Nominal Capacity/F.L.Rate=1,200 mbh / 12.90 Therms] (Heating Equipment)													
Gas (therms)	1,338.5	1,242.1	1,191.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,108.1	1,257.0	6,137.3
Peak (therms/Hr)	5.1	5.1	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.1	5.1

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 1 Manalapan Building Envelope Improvement

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=578.2 mbh]													
Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	3,698.7	3,340.8	3,698.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,579.4	3,698.7	18,016.2
Peak (kW)	5.0	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0	5.0
Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	892.8	806.4	892.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	864.0	892.8	4,348.8
Peak (kW)	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	1.2
Cntl panel & interlocks - 0.5 KW (Misc Accessory Equipment)													
Electric (kWh)	372.0	336.0	372.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.0	372.0	1,812.0
Peak (kW)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5
Sys 1: AHU-5													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=4,181 cfm / 7.08 kW] (Main Clg Fan)													
Electric (kWh)	4,874.3	4,407.1	4,832.7	4,596.1	4,650.0	4,365.0	4,429.5	4,335.6	4,492.5	4,747.8	4,701.3	4,892.9	55,324.9
Peak (kW)	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=4,203 cfm / 3.54 kW] (Main Return Fan)													
Electric (kWh)	2,608.4	2,365.0	2,621.1	2,524.2	2,609.0	2,523.8	2,576.7	2,567.7	2,520.1	2,607.6	2,531.0	2,611.2	30,665.8
Peak (kW)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Sys 2: AHU-2													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,786 cfm / 5.31 kW] (Main Clg Fan)													
Electric (kWh)	1,450.5	1,317.9	1,588.6	1,284.4	1,519.6	1,519.6	1,397.0	1,588.6	1,381.4	1,451.6	1,450.5	1,381.4	17,331.0
Peak (kW)	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,793 cfm / 2.13 kW] (Main Return Fan)													
Electric (kWh)	579.5	527.6	636.1	514.3	609.0	608.3	559.4	635.4	553.0	580.2	580.0	552.5	6,935.0
Peak (kW)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Sys 3: AHU-3													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=10,624 cfm / 3.54 kW] (Main Clg Fan)													
Electric (kWh)	2,351.2	2,131.6	2,374.1	2,363.0	2,532.9	2,427.8	2,526.8	2,511.0	2,460.8	2,368.1	2,238.5	2,362.4	28,648.2
Peak (kW)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 1 Manalapan Building Envelope Improvement

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Sys 3: AHU-3													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=10,635 cfm / 0.67 kW] (Main Return Fan)													
Electric (kWh)	499.9	451.8	500.3	483.3	499.5	483.7	500.1	499.9	483.2	500.0	483.9	500.0	5,885.4
Peak (kW)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Sys 4: AHU-1													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=6,987 cfm / 10.63 kW] (Main Clg Fan)													
Electric (kWh)	7,931.2	7,163.7	7,931.2	7,675.4	7,563.4	7,206.0	7,522.8	7,412.2	7,111.5	7,931.2	7,675.4	7,931.2	91,055.2
Peak (kW)	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=7,012 cfm / 1.42 kW] (Main Return Fan)													
Electric (kWh)	1,050.2	950.3	1,052.7	1,018.0	1,053.4	1,018.5	1,052.2	1,051.5	1,018.0	1,050.5	1,017.1	1,051.0	12,383.4
Peak (kW)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Sys 5: AHU-4													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=6,516 cfm / 7.08 kW] (Main Clg Fan)													
Electric (kWh)	4,894.6	4,436.1	4,695.3	4,688.2	4,695.9	4,561.5	4,738.5	4,618.9	4,716.5	4,511.0	4,587.5	4,936.6	56,080.5
Peak (kW)	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=6,532 cfm / 2.13 kW] (Main Return Fan)													
Electric (kWh)	1,578.5	1,427.6	1,581.2	1,529.4	1,581.9	1,522.4	1,578.8	1,572.0	1,529.4	1,578.9	1,528.5	1,579.3	18,588.0
Peak (kW)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 2 New VAV Boxes

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Lights													
Electric (kWh)	12,842.4	11,599.6	12,842.4	12,428.1	12,842.4	12,428.1	12,842.4	12,842.4	12,428.1	12,842.4	12,428.1	12,842.4	151,208.6
Peak (kW)	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3
Misc. Ld													
Electric (kWh)	3,821.1	3,451.3	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	3,821.1	3,697.9	3,821.1	3,697.9	3,821.1	44,990.8
Peak (kW)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Cooling Coil Condensate													
Recoverable Water (1000gal)	0.0	0.0	0.0	0.0	0.4	3.0	2.6	3.0	2.2	0.0	0.0	0.0	11.2
Peak (1000gal/Hr)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bsu 1: Manalapan Dom HW & Cooking													
Gas (therms)	148.8	134.4	148.8	144.0	148.8	144.0	148.8	148.8	144.0	148.8	144.0	148.8	1,752.0
Peak (therms/Hr)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=74.23 tons]													
Air-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=120 tons / 136.8 kW] (Cooling Equipment)													
Electric (kWh)	0.0	0.0	0.0	1,108.4	4,116.4	12,384.7	16,964.5	16,316.7	8,966.0	615.1	0.0	0.0	60,471.8
Peak (kW)	0.0	0.0	0.0	20.5	40.5	51.0	61.0	58.1	45.8	20.3	0.0	0.0	61.0
Condenser fan for Centrifugal [Design Heat Rejection/F.L.Rate=158.9 tons / 15.10 kW]													
Electric (kWh)	0.0	0.0	0.0	187.9	685.2	1,993.9	2,606.4	2,532.1	1,461.0	104.4	0.0	0.0	9,570.8
Peak (kW)	0.0	0.0	0.0	3.3	6.2	7.3	7.9	7.7	6.7	2.4	0.0	0.0	7.9
Manalapan Pumps with Controls (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	2.9	24.8	164.5	228.5	220.6	88.7	1.2	0.0	0.0	731.1
Peak (kW)	0.0	0.0	0.0	0.2	1.2	1.9	2.3	2.1	1.5	0.1	0.0	0.0	2.3
Cntl panel & interlocks - 1 KW (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	276.0	483.0	702.0	744.0	744.0	620.0	235.0	0.0	0.0	3,804.0
Peak (kW)	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=573.8 mbh]													
Boiler - 001 [Nominal Capacity/F.L.Rate=1,200 mbh / 12.90 Therms] (Heating Equipment)													
Gas (therms)	1,320.4	1,223.6	1,180.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,099.8	1,243.6	6,067.9
Peak (therms/Hr)	5.0	5.1	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0	5.1

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 2 New VAV Boxes

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=573.8 mbh]													
Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	3,698.7	3,340.8	3,698.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,579.4	3,698.7	18,016.2
Peak (kW)	5.0	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0	5.0
Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	892.8	806.4	892.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	864.0	892.8	4,348.8
Peak (kW)	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	1.2
Cntl panel & interlocks - 0.5 KW (Misc Accessory Equipment)													
Electric (kWh)	372.0	336.0	372.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.0	372.0	1,812.0
Peak (kW)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5
Sys 1: AHU-5													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=4,259 cfm / 7.08 kW] (Main Clg Fan)													
Electric (kWh)	4,874.5	4,401.3	4,832.2	4,594.5	4,640.2	4,364.1	4,416.0	4,331.4	4,486.1	4,742.9	4,701.5	4,893.1	55,277.9
Peak (kW)	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=4,280 cfm / 3.54 kW] (Main Return Fan)													
Electric (kWh)	2,608.9	2,362.4	2,621.4	2,524.5	2,609.3	2,524.1	2,576.6	2,568.1	2,520.5	2,608.1	2,531.4	2,611.6	30,666.8
Peak (kW)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Sys 2: AHU-2													
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,809 cfm / 5.31 kW] (Main Clg Fan)													
Electric (kWh)	1,450.5	1,317.3	1,588.6	1,283.7	1,519.6	1,519.6	1,396.9	1,588.6	1,381.4	1,454.4	1,450.5	1,381.4	17,332.4
Peak (kW)	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
FC Centrifugal const vol [DsnAirflow/F.L.Rate=1,816 cfm / 2.13 kW] (Main Return Fan)													
Electric (kWh)	579.5	527.4	636.1	514.0	608.9	608.3	559.3	635.4	553.0	581.3	580.0	552.5	6,935.6
Peak (kW)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Sys 3: AHU-3													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=10,741 cfm / 3.54 kW] (Main Clg Fan)													
Electric (kWh)	2,352.6	2,133.4	2,300.5	2,360.5	2,533.1	2,428.4	2,527.0	2,511.4	2,461.1	2,368.1	2,238.6	2,363.2	28,577.8
Peak (kW)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6

EQUIPMENT ENERGY CONSUMPTION
By Trane

Alternative: 2 New VAV Boxes

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Consumption -------												
Sys 3: AHU-3													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=10,752 cfm / 0.67 kW] (Main Return Fan)													
Electric (kWh)	499.9	451.8	500.3	483.3	499.5	483.7	500.1	500.0	483.2	500.0	483.9	500.0	5,885.5
Peak (kW)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Sys 4: AHU-1													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=7,075 cfm / 10.63 kW] (Main Clg Fan)													
Electric (kWh)	7,931.2	7,163.7	7,931.2	7,675.4	7,601.4	7,205.8	7,535.1	7,412.1	7,115.0	7,931.2	7,675.4	7,931.2	91,108.6
Peak (kW)	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=7,100 cfm / 1.42 kW] (Main Return Fan)													
Electric (kWh)	1,050.3	950.4	1,052.8	1,018.1	1,053.5	1,018.6	1,052.2	1,051.6	1,018.1	1,050.6	1,017.2	1,051.0	12,384.3
Peak (kW)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Sys 5: AHU-4													
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=6,611 cfm / 7.08 kW] (Main Clg Fan)													
Electric (kWh)	4,882.2	4,416.9	4,706.6	4,589.6	4,696.2	4,567.5	4,676.0	4,595.9	4,518.6	4,505.6	4,595.9	4,923.8	55,674.6
Peak (kW)	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=6,627 cfm / 2.13 kW] (Main Return Fan)													
Electric (kWh)	1,578.6	1,427.7	1,581.3	1,529.5	1,582.0	1,522.5	1,578.9	1,572.1	1,529.5	1,579.0	1,528.6	1,579.4	18,589.1
Peak (kW)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1

System Checksums

By Trane

AHU-1 **Terminal Reheat**

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 17
Outside Air: OADB/WB/HR: 87 / 74 / 108

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	5,169	0	5,169	2
Skylite Cond	0	34	34	0
Roof Cond	0	131,165	131,165	53
Glass Solar	28,839	0	28,839	12
Glass/Door Cond	1,504	0	1,504	1
Wall Cond	4,892	823	5,715	2
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	11,550		11,550	5
Sub Total ==>	51,954	132,022	183,976	74
Internal Loads				
Lights	14,554	3,639	18,192	7
People	12,600	0	12,600	5
Misc	5,791	0	5,791	2
Sub Total ==>	32,945	3,639	36,583	15
Ceiling Load	37,879	-37,879	0	0
Ventilation Load	0	0	12,150	5
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	10,857		10,857	4
Exhaust Heat		-7,671	-7,671	-3
Sup. Fan Heat			9,663	4
Ret. Fan Heat		2,006	2,006	1
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	133,635	92,117	247,564	100.00

CLG SPACE PEAK

Mo/Hr: Sum of
OADB: Peaks

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	5,486	5
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	33,036	29
Glass/Door Cond	950	1
Wall Cond	4,954	4
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	3,037	3
Sub Total ==>	47,463	42
Internal Loads		
Lights	14,554	13
People	7,000	6
Misc	5,791	5
Sub Total ==>	27,345	24
Ceiling Load	36,514	32
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing	2,276	2
Grand Total ==>	113,598	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	-2,026	1.28
Roof Cond	0	-100,525	63.64
Glass Solar	0	0	0.00
Glass/Door Cond	-8,258	-8,258	5.23
Wall Cond	-9,016	-11,072	7.01
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-16,735	-16,735	10.59
Sub Total ==>	-34,010	-138,616	87.76
Internal Loads			
Lights	0	0	0.00
People	7,000	7,000	-4.43
Misc	0	0	0.00
Sub Total ==>	7,000	7,000	-4.43
Ceiling Load	-29,403	0	0.00
Ventilation Load	0	-18,956	12.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		5,857	-3.71
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-13,243	8.38
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-56,412	-157,957	100.00

TEMPERATURES

	Cooling	Heating
SADB	59.3	79.8
Ra Plenum	87.9	62.0
Return	87.9	62.0
Ret/OA	87.9	59.8
Fn MtrTD	0.1	0.0
Fn BldTD	0.3	0.0
Fn Frict	0.9	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	6,522	6,522
Terminal	6,522	6,522
Main Fan	6,522	6,522
Sec Fan	0	0
Nom Vent	280	280
AHU Vent	280	280
Infil	247	247
MinStop/Rh	6,522	6,522
Return	6,769	6,769
Exhaust	527	527
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	4.3	4.3
cfm/ft²	0.70	0.70
cfm/ton	316.15	
ft²/ton	449.34	
Btu/hr·ft²	26.71	-17.04
No. People	28	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter DB/WB/HR °F	Enter DB/WB/HR gr/lb	Leave DB/WB/HR °F	Leave DB/WB/HR °F	Leave DB/WB/HR gr/lb
Main Clg	20.6	247.6	224.8	6,522	88.5	67.2	66.3	58.0	55.1	60.4
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	20.6	247.6								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	9,270		
Part	0		
Int Door	0		
ExFlr	0		
Roof	9,270	38	0
Wall	3,270	218	7
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-158.0	6,522	58.0	79.8
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-158.0			

Project Name:
Dataset Name: BASELINE.TRC

System Checksums

By Trane

AHU-2 **Terminal Reheat**

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 16
Outside Air: OADB/WB/HR: 88 / 75 / 111

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	35,589	35,589	44
Glass Solar	5,693	0	5,693	7
Glass/Door Cond	1,629	0	1,629	2
Wall Cond	1,230	243	1,473	2
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	3,048		3,048	4
Sub Total ==>	11,599	35,832	47,431	58
Internal Loads				
Lights	3,858	964	4,822	6
People	13,500	0	13,500	17
Misc	1,390	0	1,390	2
Sub Total ==>	18,747	964	19,712	24
Ceiling Load	10,357	-10,357	0	0
Ventilation Load	0	0	13,955	17
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	4,818		4,818	6
Exhaust Heat		-5,451	-5,451	-7
Sup. Fan Heat			818	1
Ret. Fan Heat		265	265	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	45,521	21,254	81,548	100.00

CLG SPACE PEAK

Mo/Hr: Sum of
OADB: Peaks

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	19,746	53
Glass/Door Cond	542	1
Wall Cond	719	2
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	465	1
Sub Total ==>	21,473	57
Internal Loads		
Lights	3,858	10
People	7,500	20
Misc	1,390	4
Sub Total ==>	12,747	34
Ceiling Load	3,226	9
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing	1	0
Grand Total ==>	37,448	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-26,799	46.05
Glass Solar	0	0	0.00
Glass/Door Cond	-7,728	-7,728	13.28
Wall Cond	-2,301	-2,943	5.06
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-4,436	-4,436	7.62
Sub Total ==>	-14,465	-41,906	72.01
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-7,724	0	0.00
Ventilation Load	0	-20,309	34.90
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		4,024	-6.92
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-22,188	-58,191	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.4	83.6
Ra Plenum	88.3	62.1
Return	88.4	62.1
Ret/OA	88.4	53.2
Fn MtrTD	0.0	0.0
Fn BldTD	0.1	0.0
Fn Frict	0.3	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	1,725	1,725
Terminal	1,725	1,725
Main Fan	1,725	1,725
Sec Fan	0	0
Nom Vent	300	300
AHU Vent	300	300
Infil	66	66
MinStop/Rh	1,725	1,725
Return	1,791	1,791
Exhaust	366	366
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	17.4	17.4
cfm/ft²	0.70	0.70
cfm/ton	253.88	
ft²/ton	361.55	
Btu/hr·ft²	33.19	-23.68
No. People	30	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter DB/WB/HR °F	Enter DB/WB/HR gr/lb	Leave DB/WB/HR °F	Leave DB/WB/HR °F	Leave DB/WB/HR gr/lb
Main Clg	6.8	81.6	64.0	1,725	88.4	68.5	73.1	55.0	53.4	58.7
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	6.8	81.6								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	2,457		
Part	0		
Int Door	0		
ExFlr	0		
Roof	2,457	0	0
Wall	1,020	204	20
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-54.7	1,725	55.0	83.6
Aux Htg	0.0	0	0.0	0.0
Preheat	-3.5	1,725	53.2	55.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-58.2			

System Checksums

By Trane

AHU-3 **Terminal Reheat**

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 17
Outside Air: OADB/WB/HR: 87 / 74 / 108

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	33,591	0	33,591	14
Skylite Cond	0	2,477	2,477	1
Roof Cond	0	61,848	61,848	27
Glass Solar	82,981	0	82,981	36
Glass/Door Cond	4,017	0	4,017	2
Wall Cond	296	283	579	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	4,794		4,794	2
Sub Total ==>	125,680	64,608	190,288	82
Internal Loads				
Lights	6,486	1,621	8,107	3
People	6,300	0	6,300	3
Misc	2,337	0	2,337	1
Sub Total ==>	15,123	1,621	16,744	7
Ceiling Load	6,795	-6,795	0	0
Ventilation Load	0	0	6,044	3
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	4,518		4,518	2
Exhaust Heat		-1,478	-1,478	-1
Sup. Fan Heat			15,126	6
Ret. Fan Heat		1,529	1,529	1
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	152,115	59,486	232,771	100.00

CLG SPACE PEAK

Mo/Hr: Sum of
OADB: Peaks

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	33,591	23
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	88,253	61
Glass/Door Cond	3,746	3
Wall Cond	118	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	1,436	1
Sub Total ==>	127,144	87
Internal Loads		
Lights	6,486	4
People	3,459	2
Misc	2,337	2
Sub Total ==>	12,282	8
Ceiling Load	6,180	4
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing	202	0
Grand Total ==>	145,809	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	-20,479	12.65
Roof Cond	0	-45,111	27.87
Glass Solar	0	0	0.00
Glass/Door Cond	-20,229	-20,229	12.50
Wall Cond	-429	-986	0.61
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-7,458	-7,458	4.61
Sub Total ==>	-28,115	-94,262	58.24
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-6,784	0	0.00
Ventilation Load	0	-9,478	5.86
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		1,439	-0.89
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-59,540	36.79
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-34,899	-161,840	100.00

TEMPERATURES

	Cooling	Heating
SADB	62.1	75.1
Ra Plenum	80.2	66.8
Return	80.3	66.8
Ret/OA	80.4	66.1
Fn MtrTD	0.1	0.0
Fn BldTD	0.3	0.0
Fn Frict	0.9	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	10,210	10,210
Terminal	10,210	10,210
Main Fan	10,210	10,210
Sec Fan	0	0
Nom Vent	140	140
AHU Vent	140	140
Infil	110	110
MinStop/Rh	10,210	10,210
Return	10,320	10,320
Exhaust	250	250
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	1.4	1.4
cfm/ft²	2.47	2.47
cfm/ton	526.36	
ft²/ton	212.96	
Btu/hr·ft²	56.35	-39.18
No. People	14	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter DB/WB/HR °F	Enter DB/WB/HR gr/lb	Leave DB/WB/HR °F	Leave DB/WB/HR °F	Leave DB/WB/HR gr/lb
Main Clg	19.4	232.8	222.5	10,210	80.4	64.4	65.6	60.8	57.1	64.1
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	19.4	232.8								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	4,131		
Part	0		
Int Door	0		
ExFlr	0		
Roof	4,131	346	8
Wall	810	534	66
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-161.8	10,210	60.8	75.1
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-161.8			

System Checksums

By Trane

AHU-4 **Terminal Reheat**

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 17
Outside Air: OADB/WB/HR: 87 / 74 / 108

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	3,446	0	3,446	1
Skylite Cond	0	94	94	0
Roof Cond	0	82,248	82,248	35
Glass Solar	53,645	0	53,645	23
Glass/Door Cond	2,729	0	2,729	1
Wall Cond	2,873	604	3,477	1
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	8,548		8,548	4
Sub Total ==>	71,240	82,946	154,186	66
Internal Loads				
Lights	16,668	4,167	20,834	9
People	15,157	0	15,157	6
Misc	3,434	0	3,434	1
Sub Total ==>	35,259	4,167	39,426	17
Ceiling Load	17,547	-17,547	0	0
Ventilation Load	0	0	14,842	6
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	18,541		18,541	8
Exhaust Heat		-5,382	-5,382	-2
Sup. Fan Heat			9,858	4
Ret. Fan Heat		2,026	2,026	1
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	142,587	66,210	233,497	100.00

CLG SPACE PEAK

Mo/Hr: Sum of
OADB: Peaks

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	3,657	3
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	59,794	51
Glass/Door Cond	2,087	2
Wall Cond	3,168	3
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	2,167	2
Sub Total ==>	70,874	61
Internal Loads		
Lights	16,668	14
People	7,272	6
Misc	3,434	3
Sub Total ==>	27,374	23
Ceiling Load	16,561	14
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing	2,177	2
Grand Total ==>	116,986	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	-1,415	0.91
Roof Cond	0	-68,951	44.19
Glass Solar	0	0	0.00
Glass/Door Cond	-17,653	-17,653	11.31
Wall Cond	-6,700	-8,550	5.48
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-12,368	-12,368	7.93
Sub Total ==>	-36,721	-108,937	69.82
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-14,605	0	0.00
Ventilation Load	0	-23,017	14.75
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		4,404	-2.82
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-28,466	18.25
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-51,327	-156,016	100.00

TEMPERATURES

	Cooling	Heating
SADB	59.2	79.0
Ra Plenum	84.1	64.4
Return	83.7	64.4
Ret/OA	83.8	61.7
Fn MtrTD	0.1	0.0
Fn BldTD	0.3	0.0
Fn Frict	0.9	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	6,654	6,654
Terminal	6,654	6,654
Main Fan	6,654	6,654
Sec Fan	0	0
Nom Vent	340	340
AHU Vent	340	340
Infil	183	183
MinStop/Rh	6,654	6,654
Return	6,837	6,837
Exhaust	523	523
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	5.1	5.1
cfm/ft²	1.10	1.10
cfm/ton	341.98	
ft²/ton	312.00	
Btu/hr·ft²	38.46	-25.70
No. People	34	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter DB/WB/HR °F	Enter DB/WB/HR gr/lb	Leave DB/WB/HR °F	Leave DB/WB/HR °F	Leave DB/WB/HR gr/lb
Main Clg	19.5	233.5	209.2	6,654	85.5	66.3	66.3	57.8	54.9	60.1
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	19.5	233.5								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	6,071		
Part	0		
Int Door	0		
ExFlr	0		
Roof	6,071	25	0
Wall	2,810	466	17
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-156.0	6,654	57.8	79.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-156.0			

Project Name:
Dataset Name: BASELINE.TRC

System Checksums

By Trane

AHU-5

Terminal Reheat

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 8 / 16
Outside Air: OADB/WB/HR: 87 / 77 / 125

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	0	0	0
Glass Solar	41,955	0	41,955	28
Glass/Door Cond	1,941	0	1,941	1
Wall Cond	3,245	915	4,160	3
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	13,915		13,915	9
Sub Total ==>	61,057	915	61,972	41
Internal Loads				
Lights	22,211	5,553	27,763	18
People	15,178	0	15,178	10
Misc	4,577	0	4,577	3
Sub Total ==>	41,965	5,553	47,517	32
Ceiling Load	2,119	-2,119	0	0
Ventilation Load	0	0	19,019	13
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	13,307		13,307	9
Exhaust Heat		-824	-824	-1
Sup. Fan Heat			7,717	5
Ret. Fan Heat		2,047	2,047	1
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	118,448	5,572	150,756	100.00

CLG SPACE PEAK

Mo/Hr: Sum of
OADB: Peaks

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	44,236	50
Glass/Door Cond	532	1
Wall Cond	3,507	4
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	3,387	4
Sub Total ==>	51,662	58
Internal Loads		
Lights	22,211	25
People	8,378	9
Misc	4,577	5
Sub Total ==>	35,165	39
Ceiling Load	2,104	2
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing		
Exhaust Heat	138	0
Grand Total ==>		100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-15,759	-15,759	12.63
Wall Cond	-7,911	-10,268	8.23
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-17,984	-17,984	14.41
Sub Total ==>	-41,654	-44,011	35.27
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-787	0	0.00
Ventilation Load	0	-23,017	18.45
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		206	-0.17
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-57,952	46.45
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-42,441	-124,774	100.00

TEMPERATURES

	Cooling	Heating
SADB	56.5	80.8
Ra Plenum	75.8	71.7
Return	76.2	71.7
Ret/OA	77.0	66.9
Fn MtrTD	0.2	0.0
Fn BldTD	0.4	0.0
Fn Frict	1.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	4,341	4,341
Terminal	4,341	4,341
Main Fan	4,341	4,341
Sec Fan	0	0
Nom Vent	340	340
AHU Vent	340	340
Infil	266	266
MinStop/Rh	4,341	4,341
Return	4,607	4,607
Exhaust	606	606
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	7.8	7.8
cfm/ft²	0.54	0.54
cfm/ton	345.54	
ft²/ton	643.95	
Btu/hr·ft²	18.63	-15.42
No. People	34	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter DB/WB/HR °F	Enter DB/WB/HR gr/lb	Leave DB/WB/HR °F	Leave DB/WB/HR °F	Leave DB/WB/HR gr/lb
Main Clg	12.6	150.8	119.5	4,341	77.1	64.0	68.7	54.9	52.2	54.3
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	12.6	150.8								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	8,090		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	3,150	416	13
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-124.8	4,341	54.9	80.8
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-124.8			

Project Name:
Dataset Name: BASELINE.TRC

Energy Savings Report
ECM # 1 Cooling Plant Upgrade

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	Outside behind building & in first floor mechanical room
Product or Process:	Chilled water plant upgrade
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Michael Phillips, Project Manager

Tozour Energy Services
THE POWER TO SAVE

Project Scope Definition

Project will consist of removal and demolition of existing chiller, installation of new chiller including all associated mounting, electrical, and piping work. Installation of new chilled water pumps with premium efficiency pump motors and a Variable Frequency Drive (VFD) Package including system balancing.

The existing chiller will be replaced with the highest efficiency model available in an air-cooled model. The CDM energy audit used a savings example featuring a new machine with a full load Energy Efficiency Ratio (EER) of 11.0 which is equal to a Coefficient of Performance (COP) of 3.2, which is the equivalent of 1.09 kilowatts per ton (kW/Ton). The highest efficiency available for an air-cooled chiller is an EER of 10.5 = kW/Ton of 1.14. This efficiency rating is 9.8% better than what will be required by ASHRAE 90.1-2010 which requires an EER of 9.562. The installation of a high efficiency machine will improve facility comfort while driving down energy costs.

Premium efficiency electric motors will help to optimize pumping systems efficiency, reduce electrical power consumption and costs, and improve system reliability. Premium efficiency motors run cooler, last longer, and require less maintenance than the existing standard efficiency motors. Premium efficiency motors can be as high as 95% efficient as opposed to standard efficiency motors of 78% to 88%. Premium efficiency motors are also designed to operate well at varying speed allowing variable Frequency Drive (VFD) installations where applicable. Energy savings from VFD motors will increase savings up to 20%.

Testing & Balancing (T&B) of chilled water systems is a crucial task in the process of ensuring optimum energy efficiency of chillers and the units they serve. T&B will match the output of each system to it's load. HVAC systems are balanced to deliver the proper amount of water to maintain comfort and efficiency. Too much or too little chilled water delivered to a cooling load results in energy waste as well as occupant discomfort.

Existing Conditions & Planned Improvements



Existing air-cooled chiller



New CGAM scroll chiller



Variable Frequency Drive (VFD)

The existing chiller (pictured above) serving the Manalapan main building & Police headquarters is an air-cooled Bohn machine rated at 118 tons. Maintenance records performed in June indicate that only 2 of the machines 4 compressors are still functioning and the maximum capacity of the chiller may only be 60 tons at this point. The pumping system is currently a constant volume flow system. The new system will employ a VFD package capable of adjusting flow to the most efficient level. NOTE: a geothermal chillerhad been considered for this ECM but was ultimately rejected due to having too long of a payback (self-funding) period. This chiller requires the drilling of a bore field for ground source water which increased the cost of the projec. Although very efficent, the payback thistype of system exceeded 19 years. It is a better option for larger buildings.

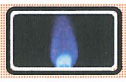
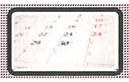
Energy Savings Report

ECM # 1 Cooling Plant Upgrade

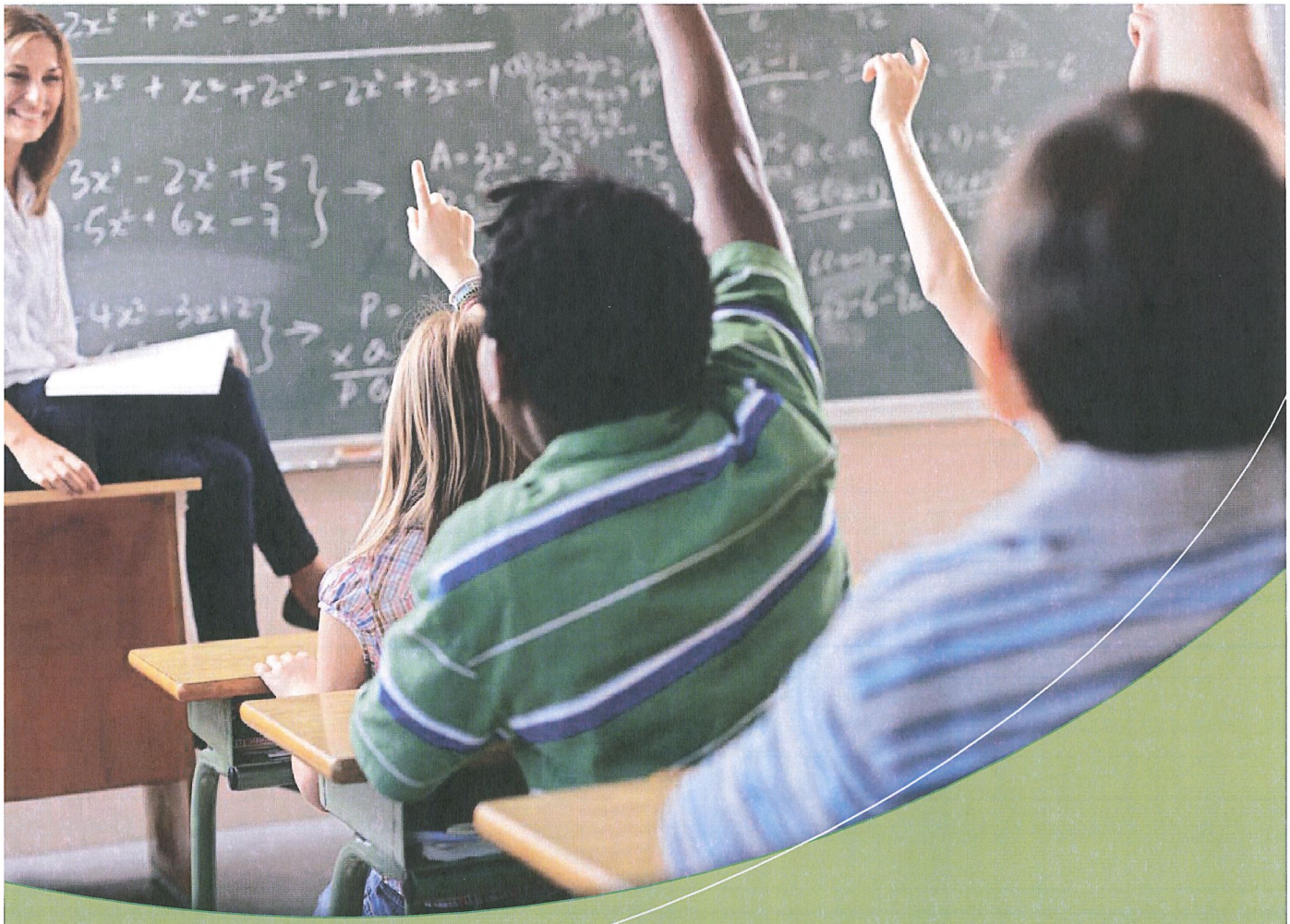
Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	Outside behind building & in first floor mechanical room
Product or Process:	Chilled water plant upgrade
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Michael Phillips, Project Manager

Tozour Energy Services
THE POWER TO SAVE

Cost & Savings Analysis - Savings calculated by the Trace 700 building model simulation program

	Installation Cost	$122,903	
	Reduction in Electric Consumption	124,374	kWh
	Reduction in Electric Demand	31	kW
	Reduction in Natural Gas	0	dTh
	Electrical Consumption Cost	$0.1645	/ kWh
	Electrical Demand Cost	$0.00	/ kW
	Natural Gas Cost	$12.29	/ dTh
	Annual Energy Savings	$20,456	
	Annual Operational Savings	$0	
	Annual Total Savings	$20,456	
	Pay for Performance Incentive	$27,362	
	Simple Payback - No Incentive	6.0	Years
	Simple Payback with P4P Incentive	4.7	Years
	Reduction in CO_2	93	Tons
	Equivalent Additional Trees	466	Trees
	Equivalent Reduction in Automobiles	16	Cars

TRANE



CGAM air-cooled scroll chiller

Highly efficient, yet extremely quiet

Ingersoll Rand

Balancing energy efficiency and quiet operation

Energy efficiency, sound, reliability, controls and service are all vitally important to the effective operation of a building. Trane engineers know how important all these factors are to you—so we designed them all into our new 20-130 ton model CGAM chiller. Using the best elements of each design we created an extremely quiet and highly efficient chiller.

High efficiency and quiet operation

Most air-cooled chillers require you to choose between a highly-efficient unit or a low-noise unit. A quieter fan often produces less air flow, reducing efficiency. With the Trane CGAM chiller, we have designed these two very important benefits into one chiller.

Our design team compiled the best approaches from around the globe to optimize the CGAM chiller so that it meets global green initiatives and ASHRAE energy efficiency standards.

The Trane CGAM chiller is one of the most efficient air-cooled chillers, even among screw compressor equipment. Low sound levels are standard, with a 5–8db reduction compared to previous Trane air-cooled chiller models. And, with factory-installed attenuation, Trane further reduces sound levels—up to an additional 3db.

Reliability you can count on

Energy efficiency and quiet operation are increasingly critical. As a result, we perform extensive testing on the compressors and units, confirming their robust design and durability while ensuring our high standards for reliability.

Our testing includes:

- Extreme testing includes cold ambient starts, hot water starts and high ambient operation
- Compressor accelerated life cycle testing, including high pressure ratio, high load test, flooded starts/stops, start/stop testing and phase reversal



On-site test facility ensures reliability and performance verification

3 Air-cooled scroll chiller

- Performance modeling and verification, both during design and for the life of the chiller
- FEA analysis confirms the unit structure can withstand shipping, rigging and operational activity
- Electrical testing with destructive testing for short circuit withstand rating

To minimize leaks, Trane improved the coil structure stability by strengthening the coil frame and changing the construction method. Now we use a single copper tube for two passes through the coil to reduce braze joints on one side of the coil, eliminating up to 60 joints. Furthermore, the new construction method ensures all coils are square, so the coil components are better aligned.

Factory installed reliability

We offer several factory-installed features that further reduce energy consumption, add redundancy for mission-critical operations and reduce jobsite installation time — when every day counts.

A factory-installed pump package, designed specifically for this unit, comes pre-wired and factory-tested. The dual pump setup provides built-in redundancy and the standard inverter delivers added pump energy savings.

With the factory-installed buffer tank, you can install the chiller in applications with less than a three minute water loop and still reliably maintain precise temperature control.

The flow switch and water strainer are also factory installed as standard, reducing jobsite installation requirements and ensuring reliable operation.



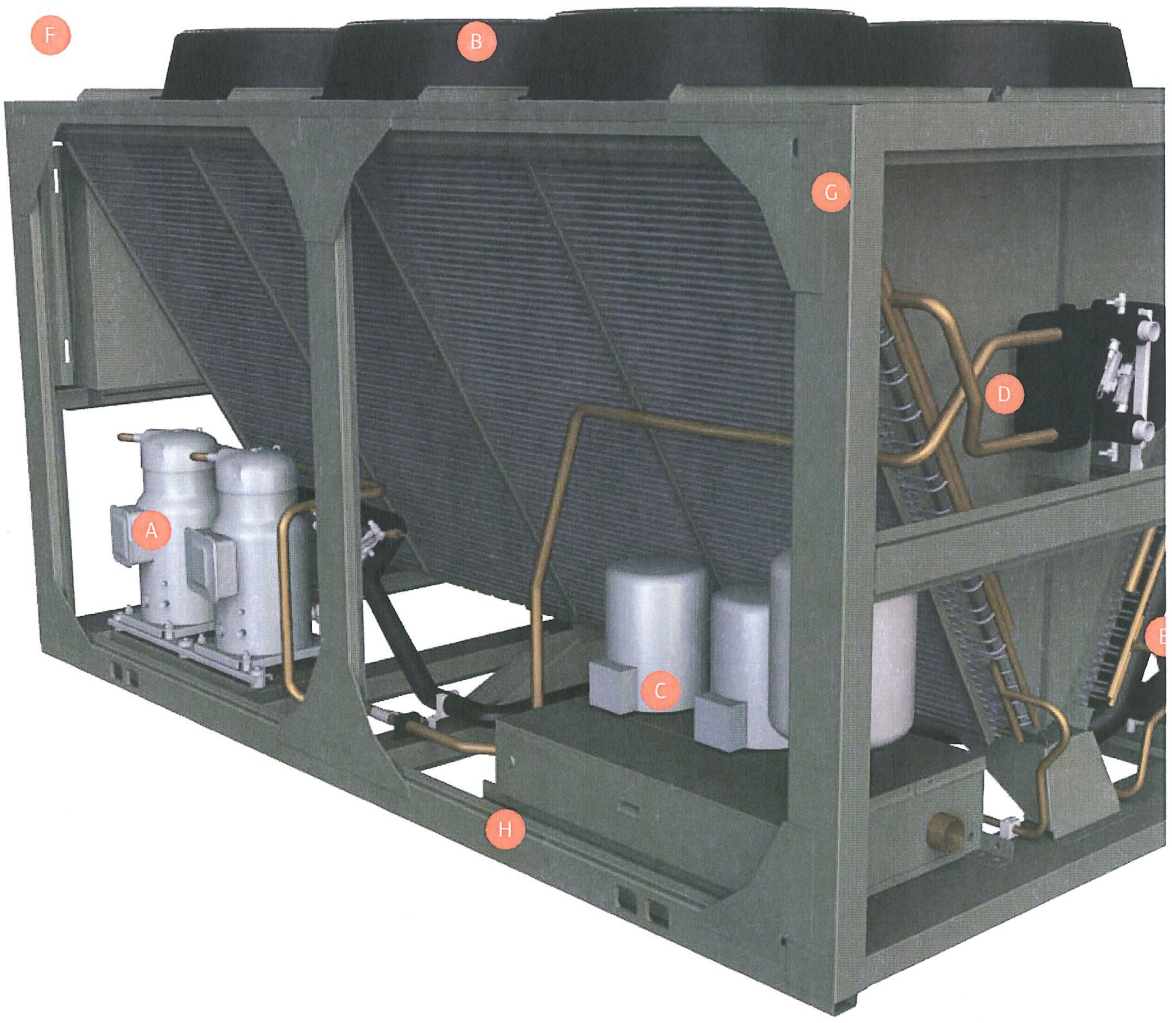
Trane reduces energy costs by incorporating an ice storage system design that uses ice made at night, when energy demand and cost are lowest, to cool the building during the day.

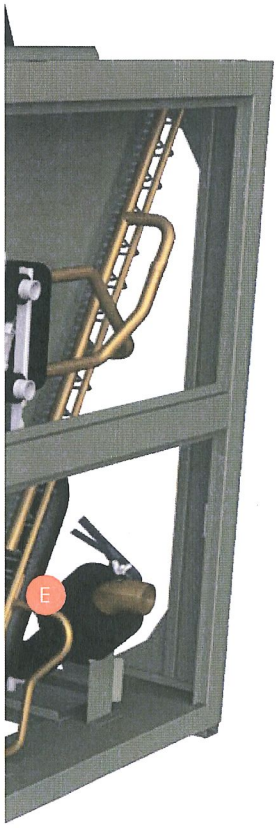
Low life cycle costs

Trane engineers, using some of the best analytic approaches and tools in the industry, can find ways to reduce your energy usage by optimizing energy efficiency and performance at every point within your system. We design systems tailored for your specific application. For example, using partial heat recovery, the heat rejected from the condenser while cooling the building can be redirected through a factory-installed heat exchanger on the chiller to provide heat for VAV reheat coils. This provides more efficient dehumidification in commercial buildings, or for pre-heating laundry or pool water in lodging applications.

Another energy saving strategy is making ice wherever energy costs are less expensive, and then using it for cooling during the day. Ice storage can be used in many applications including: K-12 schools, government jobs and industrial processes.

Air-cooled scroll chiller
Model CGAM (20-130 Ton)





- A **Compressor**—facilitates full- and part-load efficiencies that exceed ASHRAE 90.1- 2004 by 6-8%
- B **Fans**—quiet fan design is standard, 5–8 db lower than current models, with attenuation options for applications requiring ultra-quiet operation.
- C **Integration**—pump package and buffer tank are pre-wired and tested in the factory.
- D **Heat recovery**—can provide 140°F (60°C) water for use in dehumidification or other applications, such as pre-heating laundry or pool water.
- E **Reliability**—water strainer and flow switch are factory installed in the most optimum location; increased coil structure strength and reduced brazed joints minimize leaks.
- F **Controls**—CH530 improved fan staging logic for low ambient starting capability; Adaptive Controls™ are standard to maintain operation in adverse conditions.
- G **Durability**—powder-coated components and optional coated coils minimize corrosion.
- H **Serviceability**—major components are positioned for easy access. The unit structure is designed to rig pump up for easy seal changes.

Controls for reliability, efficiency and system monitoring

Trane unit controls and building automation solutions leverage our applications expertise to meet your critical requirements. Adaptive Control™ algorithms embedded in the factory-mounted CH530 controller on the CGAM chiller use Trane proprietary strategies to respond to normal, extreme or adverse conditions. The sophisticated algorithms intelligently maximize uptime while protecting equipment from damage.

The chiller manages time-of-day scheduling for small office buildings or schools without a building automation system. If an integrated pump package is included, the chiller even controls pumps as needed. For larger enterprise-wide projects, a Tracer ES™ building automation system monitors and manages all chillers within the enterprise.

Energy efficiency is more important than ever. A CH530 controller optimizes the CGAM chiller's energy consumption. New sensing technology improves control of the electronic expansion valve, further raising efficiency. Tracer Summit™ building automation provides system and building-wide energy optimization.

Building staff easily and quickly monitor operating conditions at the chiller, on site or remotely over the Web. Internet access solutions can be tailored to facility needs. The CH530 controller improves usability over the previous generation and the Tracer building automation human interface is grounded in user-centered design principles. It provides operators with consolidated reports of needed data to keep all systems running at maximum efficiency.

Recognizing integration to legacy BAS is sometimes a requirement, Trane actively supports open standard protocols. The CGAM controller integrates easily via LonTalk® or BACnet®.

Expert services for the life of the building

Trane Building Services helps you improve energy efficiency, reduce operating costs and enhance the performance of your equipment—making your building work better for life.

The CGAM chiller is available with the Trane Elite Start™ suite of services to make sure your system operates as designed from day one. Factory start-up services will help your system perform to specifications upon installation.

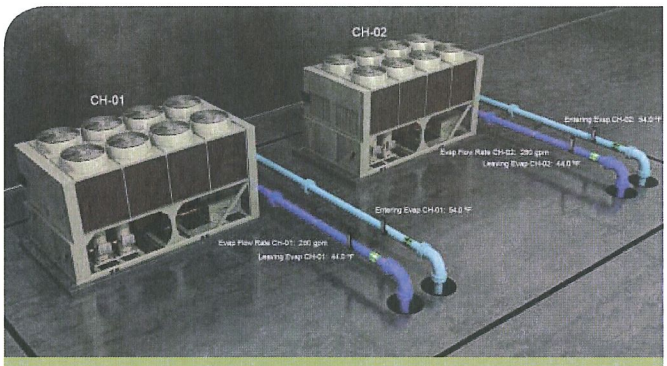


Not only do Trane CGAM air-cooled chillers deliver the lowest noise levels and highest efficiencies in their class, but they can be applied with Trane fan coil units or air-handlers to improve indoor air quality—helping achieve LEED performance.

7 Air-cooled scroll chiller

Trane recommends the following Elite Start services:

- In-Warranty Support—oil analysis, diagnostic reporting and monitoring keep equipment operation at peak performance during the first year of operation.
- Extended Warranty—covers parts and labor associated with any equipment failure.
- Service Agreements—scheduled inspections for preventive and proactive maintenance ensure long-term reliability, efficiency and performance.



Tracer Summit can manage chiller sequencing and load sensing for optimum control on site or over the Web.

Making service better

We take full advantage of the vast wealth of knowledge available to us through our service professionals by including them in our early design efforts. As a result the Trane CGAM chiller has many valuable service improvements:

- All major serviceable components are very close to the edge of the unit, making it safer and easier to service. The unit has quick and easy-to-reach service valves, water strainer and water piping connections.
- The factory-installed pump package is designed to be serviced in place, including pump seal changes. Simply lift the pump within the chiller structure to replace the seal.
- The high pressure transducer and temperature sensor mountings enable troubleshooting and replacement without refrigerant handling.
- Separate access to the low voltage control panel makes the chiller easier to service.

To help ensure that the building performance is meeting your business needs, our service professionals tap into a global network of proven best practices, Trane proprietary technology and industry-leading expertise.

We continually train our technicians and provide on-demand access to all the latest resources to make maintenance decisions that will fine-tune your entire system, in order to achieve the highest level of performance.

No service provider is more qualified to deliver the cost savings and performance assurance you demand from your Trane equipment. Trane sales and service professionals are better able to customize creative solutions that will better meet your specific maintenance, budget and operational requirements. To minimize any downtime, the Trane nationwide network of HVAC Parts and Supply stores—with access to over 300,000 items—ensures you can get the part you need when you need it.

The results you've come to expect

Take advantage of all the benefits of the Trane CGAM air-cooled chiller. Contact your local Trane account manager to learn more about how you can increase your efficiency without sacrificing quiet operation, enjoy low life cycle costs and gain the peace of mind a Trane chiller provides.

How do you know?

There are hundreds of possible system designs and chiller configurations, and thousands of possible chiller system efficiency levels. How do you narrow the choices and determine the right HVAC system design choice for your building investment?

Whether you are calculating energy efficiency to determine eligibility for LEED credits, earn tax deductions, or select the HVAC system with the lowest operating costs, Trane can help.

The System Analyzer™ helps estimate building loads and performs preliminary energy and economic analyses of virtually any building, system and equipment combination.

For LEED certification, TRACE™ 700 (Trane Air Conditioning Economics) software helps analyze the energy and economic effects of virtually any system configuration by allowing users to manipulate a wide range of variables to create a detailed energy usage profile for the specific building. Unlike overly simplified spreadsheet-based energy analysis, TRACE 700 software accurately compares the impact of building alternatives, such as architectural features, HVAC systems and other economic options, to provide true lifecycle, cost-based decisions.



Your local Trane account manager can help you find the CGAM chiller to meet your needs.

Ingersoll Rand

Ingersoll Rand (NYSE:IR) is a world leader in creating and sustaining safe, comfortable and efficient environments in commercial, residential and industrial markets. Our people and our family of brands—including Club Car®, Hussmann®, Ingersoll Rand®, Schlage®, Thermo King® and Trane®—work together to enhance the quality and comfort of air in homes and buildings, transport and protect food and perishables, secure homes and commercial properties, and increase industrial productivity and efficiency. We are a $13 billion global business committed to sustainable business practices within our company and for our customers.

© 2010 Trane All rights reserved
CG-SLB017-EN October 01, 2010

Produced on post-consumer recycled paper, using environmentally friendly print practices that reduce waste.

ingersollrand.com

Energy Savings Report
ECM # 2 Heating Plant Upgrade

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	First floor mechanical room
Product or Process:	Hot water boiler & pumping upgrade
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Michael Phillips, Project Manager

Tozour Energy Services
THE POWER TO SAVE

Project Scope Definition

Project consists of removal and demolition of existing boiler, installation of modular boilers, includes all gas and hot water piping and associated electrical work. Installation of new pumps with premium efficiency motors including system balancing.

Modular boilers have smaller footprints than larger models simplifying transportation and installation. Since boiler efficiency ratings are better with a higher load, a series of smaller boilers is ideal for energy savings by running only when they are needed. Compared to the larger hot water boilers which often run at a lower efficiency to satisfy a low heating load, modular boilers can fire at higher (more efficient) rates and meet the needs of the building. The results is less gas usage and lower energy costs.

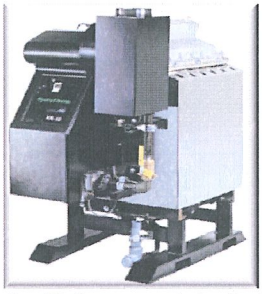
Premium efficiency electric motors will help to optimize pumping systems efficiency, reduce electrical power consumption and costs, and improve system reliability. Premium efficiency motors run cooler, last longer, and require less maintenance than the existing standard efficiency motors. Premium efficiency motors can be as high as 95% efficient as opposed to standard efficiency motors of 78% to 88%. Premium efficiency motors are also designed to operate well at varying speed allowing variable Frequency Drive (VFD) installations where applicable. Energy savings from VFD motors will increase savings up to 20%.

Testing & Balancing (T&B) of hot water systems is a crucial task in the process of ensuring optimum energy efficiency of boilers and the hot water coils they serve. T&B will match the output of the system to it's load. HVAC systems are balanced to deliver the proper amount of hot water to maintain comfort and efficiency. Too much or too little hot water delivered to a heating load results in energy waste as well as occupant discomfort.

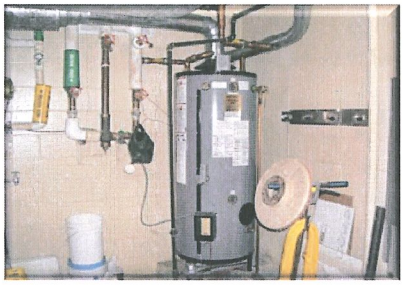
Existing Conditions & Planned Improvements



Existing gas-fired boiler



High efficiency modular boiler



Existing domestic water heater

The existing Hydrotherm gas-fired hot water heating boiler has an original efficiency rating of 80% and is rated at 1,200 MBH. Over time the efficiency of a boiler drops causing an increase in gas usage to maintain the same building conditions. The boiler's current efficiency is likely below 70% due to its age. The domestic hot water heater is fairly new and is a small load compared to the HVAC heating boiler. The domestic water heater is not included as part of the energy savings at this time. This ECM will save natural gas through greatly improved efficiency.

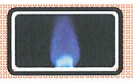
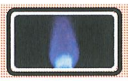
Energy Savings Report

ECM # 2 Heating Plant Upgrade

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	Outside behind building & in first floor mechanical room
Product or Process:	Hot water boiler & pumping upgrade
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Michael Phillips, Project Manager

Tozour Energy Services
THE POWER TO SAVE

Cost & Savings Analysis - Savings calculated by the Trace 700 building model simulation program

	Installation Cost	$54,492	
	Reduction in Electric Consumption	671	kWh
	Reduction in Electric Demand	0	kW
	Reduction in Natural Gas	309	dTh
	Electrical Consumption Cost	$0.1645	/ kWh
	Electrical Demand Cost	$0.00	/ kW
	Natural Gas Cost	$12.29	/ dTh
	Annual Energy Savings	$3,906	
	Annual Operational Savings	$0	
	Annual Total Savings	$3,906	
	Pay for Performance Incentive	$7,868	
	Simple Payback - No Incentive	14.0	Years
	Simple Payback with P4P Incentive	11.9	Years
	Reduction in CO_2	16	Tons
	Equivalent Additional Trees	80	Trees
	Equivalent Reduction in Automobiles	3	Cars

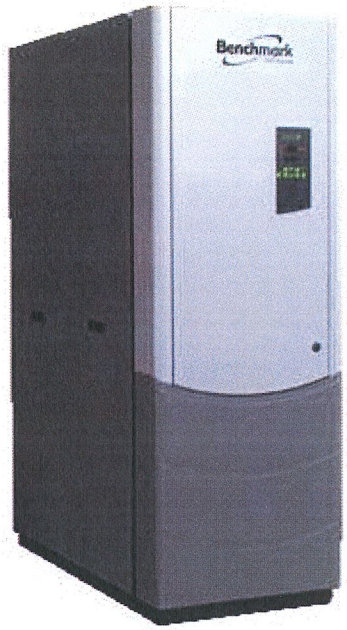
MODEL BMK-3.0LN GWB
TECHNICAL DATA

AERCO Low NOx Benchmark Gas Fired Hot Water Boiler System

The AERCO Benchmark 3.0 Low NOx (BMK 3.0LN) Water Boiler is designed for condensing application in any closed loop hydronic system. It delivers 15:1 burner turndown to match energy input directly to fluctuating system loads to yield the highest possible seasonal efficiencies. And no other product packs as much capacity into such a small footprint.

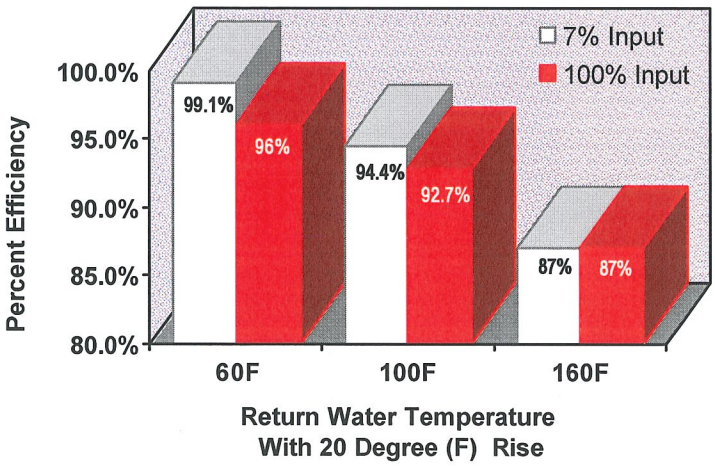
To minimize emissions, the BMK 3.0LN is fitted with a low NOx burner whose emissions will consistently measure <30 ppm of NOx corrected to 3% excess oxygen at all firing rates. The fully modulating burner also maintains AERCO standards for energy efficiency, longevity, reliability and construction quality.

The BMK 3.0LN can be used singly or in modular arrangements and offers selectable modes of operation. In addition to controlling the boiler according to a constant setpoint, indoor/outdoor reset schedule or 4-20mA signal, one or more units can be integrated via Modbus communications protocol to AERCO's multiple boiler management system (BMS) or a facility-wide Energy Management or Building Automation System.



Operating Efficiency

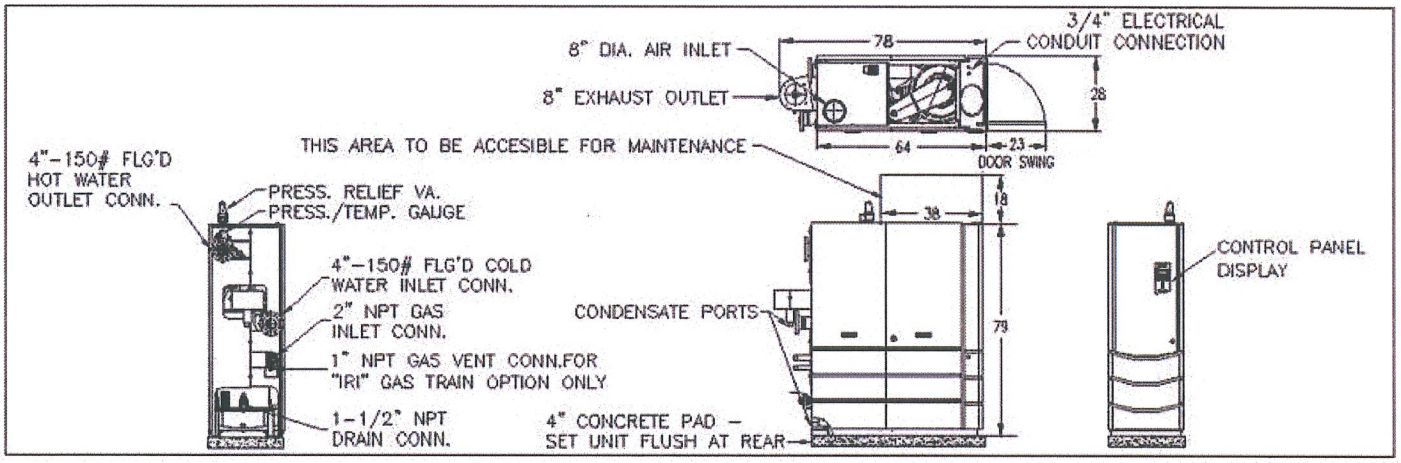
Comprehensive curves are being developed to certify the unit's efficiency over its entire 200,000 to 3,000,000 BTU/hr. operating range for a variety of operating conditions. The initial boundary tests confirm that up to 99.1% can be achieved when the unit operates at its lowest firing rate (7% input) with 60°F return water temperature. Even at 100% input, the BMK3.0LN delivers exceptional efficiency.



BMK 3.0LN Features

- **Natural Gas**
- **15:1 Turndown Ratio**
- **<30 ppm NOx Emissions at all Firing Rates**
- **Direct or Conventional Vent Capabilities**
- **AL29-4C Vent Materials Req'd per UL 1738**
- **Quiet Operation Throughout Firing Range**
- **Internal Low Water Cutoff (Manual Reset)**
- **Compact Footprint (79"H x 28"W x 64"D)**
- **Precise Temperature Control ± 2°F**
- **Sealed Combustion Capable**
- **Ventless Supply Gas Regulator**
- **UL, CUL for Alcove Installation on Combustible Flooring**

Dimensions of BMK 3.0LN Boiler



Ratings and Dimensions

Modules	Model (a)	Mbh Input (b)	Mbh Output (b) (c)	Width (1)	Depth	Height	Weight (wet)
One (1)	BMK-3.0LN	3,000 mbh	2,610mbh – 2,781mbh	2'3"	5'4"	6'5"	2,580 lbs.
Two (2)	BMK-3.0LN-2	6,000 mbh	5,220mbh – 5,562mbh	6'7"	5'4"	6'5"	5,160 lbs.
Three (3)	BMK-3.0LN-3	9,000 mbh	7,830mbh – 8,343mbh	11'0"	5'4"	6'5"	7,740 lbs.
Four (4)	BMK-3.0LN-4	12,000 mbh	10,440mbh – 11,124mbh	15'3"	5'4"	6'5"	10,320 lbs.
Five (5)	BMK-3.0LN-5	15,000 mbh	13,050mbh – 13,905mbh	19'7"	5'4"	6'5"	12,900 lbs.
Six (6)	BMK-3.0LN-6	18,000 mbh	15,660mbh – 16,686mbh	24'0"	5'4"	6'5"	15,480 lbs.
Seven (7)	BMK-3.0LN-7	21,000 mbh	18,270mbh – 19,467mbh	28'3"	5'4"	6'5"	18,060 lbs.
Eight (8)	BMK-3.0LN-8	24,000 mbh	20,880mbh – 22,248mbh	32'7"	5'4"	6'5"	20,640 lbs.

(1) Assume 24" between units. Zero side wall clearance is not provided. Consult local sales representative.
(a) Style to be determined by individual application requirement.
(b) Altitude below 2,000'. Apply altitude correction factor above 2,000'.
(c) Output dependent upon application – see efficiency curves.

BMK-3.0LN Specifications

BTU Input . . . . . .3,000,000 BTU/H*
Net Output @ Full Input . . . . . 2,610,000 – 2,781,000 BTU/H**
ASME Working Pressure . . . . . 160 PSIG
Electrical Options . . . . . 208-230/3/60 20 Amp (11 Amp FLA
460/3/60 15 Amp (5 Amp FLA)
Gas Requirements . . . . . 4" W.C. Minimum @ Full Load
2 psi Maximum
Vent Size . . . . . 8" Diameter
Water Connections . . . . . .4" Flanged 150 lb. ANSI
Gas Connection . . . . . 2" NPT
Min./Max. Water Flow . . . . . 0 GPM/350 GPM***
Water Pressure Drop . . . . . 5.5 PSIG @ 258 GPM

Water Volume . . . .49 Gallons
Control Range . . . . . 50°F to 190°F
NOx Emissions . . . . . <30 ppm at All Firing Rates
Standard Listings & Approvals . . . . . UL, CUL, CSD-1, ASME
Gas Train Options. . . . .FM Compliant or Factory Installed IRI
Weight, Installed . . . . . 2,170 lbs. (dry) 2,580 lbs. (wet)

* Up to 2000' Altitude
** Output is dependent upon return water temperature and firing rate.
*** 25 GPM water flow required for ± 2°F temperature control . Boiler can operate safely with zero water flow.

Specifications subject to change.
Consult website or AERCO.
BMK-3.0LN 6/06 10M
New Doc 6//06

AERCO International, Inc. • 159 Paris Avenue, Northvale, NJ 07647 • (P)201.768.2400 • (F)201.768.7789 • www.aerco.com • info@aerco.com

For Single Print Only

PLANT ENGINEERING®

Reed Business Information.

November 2008

PlantEngineering.com

Using condensing and modulating boilers to increase operating efficiency

By Mark Croce

AERCO International

According to the U.S. Department of Energy, almost 60% of boilers in the United States are more than 25 years old. Furthermore, it is widely accepted that these older-style, conventional boilers typically deliver less than 80% energy efficiency.

As facilities managers across the country begin to retrofit their aging boiler plants, they have the opportunity to upgrade to a new generation of gas-fired hydronic boilers. This new breed of equipment is specially designed to condense and modulate – features that enable them to operate at up to 99% thermal efficiency. This improved performance can translate to tens or hundreds of thousand of dollars of fuel savings each year.



Photo courtesy of AERCO International

Condensing and modulating boilers *can make significant contributions toward energy efficiency when effectively applied and controlled in hydronic heating applications.*

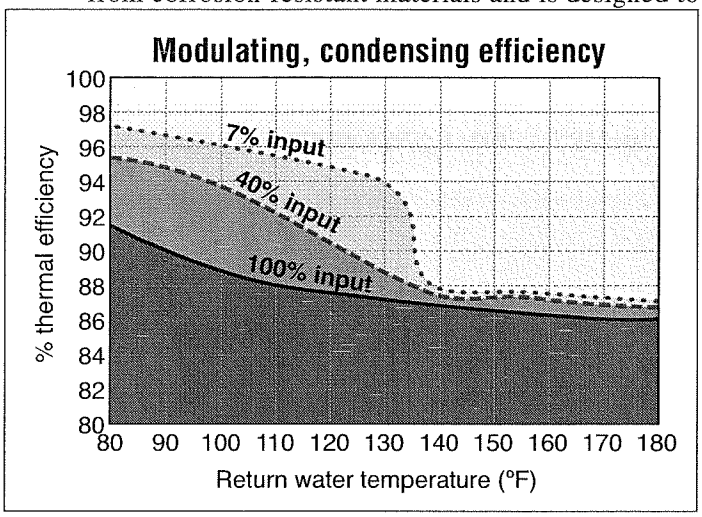
Condensing operation increases efficiency

Condensing occurs when water vapor is changed into a liquid state. Water vapor, which is a by-product of the gas-fired combustion process, is found within a boiler's exhaust gases and contains significant energy. For every pound of water vapor that is forced into a liquid state, approximately 1,000 BTU of latent energy is released in the form of heat. When this change of state takes place in the heat exchanger of a high-efficiency boiler, it is referred to as condensing operation. From within the heat exchanger, the recaptured energy can be transferred into the loop water, turning more of the boiler's fuel into usable heat. Despite its ability to deliver an estimated 11% to 12% increase in energy efficiency, not every boiler is designed for condensing operation.

While clearly desirable from an efficiency perspec-

For Single Print Only

tive, condensing has long been known to be damaging to boilers. When latent energy is extracted from the water vapor, acidic condensate remains on the surface of the heat exchanger. Unless the heat exchanger has been built from corrosion-resistant materials and is designed to drain freely, condensate will damage and destroy it over time. According to *ASHRAE Handbook 2008*, non-condensing boilers, which are fabricated using less expensive materials such as copper, cast iron and carbon steel, will corrode because of acidic condensate. Boilers designed using these materials must rely upon protective system designs to prevent condensing operation. In contrast, the heat exchangers of today's high-efficiency boilers are manufactured from superior materials such as stainless steel and aluminum, and can withstand years of condensing with no significant corrosion.



***Regardless of whether a user** has a conventional or high-efficiency boiler, flowing cold water into the heat exchanger will automatically cause most units to begin to condense, yielding greater efficiencies.*

Low return-water temperatures essential for condensing

Importantly, condensing happens naturally when the water vapor in the exhaust gases falls below its dew point. The required change of state will occur when the exhaust gases come into contact with a cool heat exchanger surface, such as when cool return water is brought to the boiler. Simply by flowing cold water (less than 130 F) into the heat exchanger, just about any boiler – conventional or high-efficiency – will automatically begin to condense to yield greater efficiencies. However, if the heat exchanger surface is not cool enough, even a condensing boiler will not operate in condensing mode.

Consequently, to leverage today's high-efficiency equipment, the system design must promote condensing operation by returning low-temperature water (less than 130 F) to the boiler, according to *ASHRAE Handbook 2008*. Whereas conventional system designs specifically employed ancillary devices such as boiler pumps, mixing valves and temperature-averaging components to pre-warm water entering the unit above 140 F to protect the boiler, today's condensing boilers can be installed directly on the heating loop. And, in addition to increasing the opportunity for condensing operation, this approach streamlines the system design, reduces project costs and helps to minimize maintenance for the life of the system.

To exploit the potential of today's condensing boilers, the *ASHRAE Handbook 2008* indicates engineers must rethink conventional 20-degree ΔT applications (i.e. 180 F supply/160 F return) in favor of high ΔT designs that promote low return water temperatures (i.e. 160 F supply/120 F return). In addition to the increased efficiency, using a 40-degree or greater ΔT also reduces pumping capacity, piping sizing and more to cut materials, installation and operational costs across the entire system. Even if somewhat constrained by an existing system's design, facility engineers can employ aggressive outdoor reset and night setback schedules to foster the low return-water temperatures needed to trigger condensing operation.

Modulation saves energy, improves comfort

Conventional boiler designs have only one level of power - 100%; they either run or are shut down. Each time a unit shuts down, the heat exchanger cools off and must be fully re-heated before transfer can begin again. When the unit is on, the 100% firing rate may be far more than what is required to meet the building's load. Such operating conditions, common in most space heating applications, lead to repeated cycling and can cause valve hunting and poor temperature control at the terminal units. The customer pays the price for cycling losses in their fuel bill and also sacrifices occupant comfort in systems that can exhibit a 10 F to 20 F variance in supply water.

Modulation refers to a boiler's ability to match firing rate – input – to meet the heating demand – output – of the system. Modulating boilers offer turndown ratios of

For Single Print Only

3:1, 4:1, 5:1 – even as high as 20:1 – to operate at less than 100% input. For example, a 1 million BTU-per-hour boiler with 20:1 turndown can operate at just 5% of its maximum capacity (that's just 50,000 BTU-per-hour) before it cycles off. Such units will then increase output in 1% increments – sometimes called "infinite" modulation – up to 100% capacity. Instead of cycling on and off, modulation allows the units operate (near) continuously, at lower capacity, to minimize cycling losses and wasteful overshoot.

According to *ASHRAE Handbook 2008*, modulating controls typically offer more precise water temperature control and higher efficiency than on/off or high/low controls.

When modulating boilers operate at part-load, less fuel is burned and energy transfer is enhanced to generate greater fuel savings.

When modulating boilers operate at part-load, less fuel is burned and energy transfer is enhanced to generate greater fuel savings. Constant operation maintains temperatures within the heat exchanger so no energy is wasted to soak the heat exchanger until it reaches optimum heat transfer condition. Such steady operation also helps maintain a constant temperature throughout the system for enhanced comfort. In addition, a low firing rate increases the time and surface area available for combustion gases to be in contact with the heat exchanger. Such enhanced contact promotes greater energy transfer.

Using multiple-unit control to maximize savings

Part-load efficiency can be further leveraged by using a boiler management system to coordinate the operations of multiple modulating units. However, not all multiple boiler controllers are created equal. Many are programmed to coordinate the operation of non-modulating boilers, bringing units online sequentially where each is assumed to be operating at 100% of capacity. While this makes sense with a plant consisting of on-off boilers, it won't maximize the enhanced part-load performance of today's fully-modulating boilers.

To demonstrate, consider a boiler plant that consists of five 2-million BTU-per-hour units, each with 20:1 turndown. While the plant can deliver anywhere between 100,000 to 10 million BTU-per-hour, it requires less fuel for all five units operating at 60% of capacity to meet a 6 million BTU-per-hour load than it would for just three of the units firing at 100%. Consequently, an appropriate control strategy would engage all five units, each firing at less than full capacity, to meet demand, rather than to only bring on three units as would occur using a sequentially staged, multiple-unit controller.

Condensing and modulating boilers can make significant contributions toward energy efficiency when effectively applied and controlled in hydronic heating applications. While equipment with these capabilities is considered to be the latest generation of high-efficiency boiler, the technologies are by no means new. In fact, commercially-sized condensing and modulating boilers have been available in the U.S. for the past 20 years. Both their operating reliability and their ability to reduce fuel bills have been performance-proven. PE

Mark Croce, marketing director at AERCO International, Northvale, NJ, has contributed to product development initiatives for the company for more than 13 years. A member of ASHRAE and the American Society of Plumbing Engineers, he holds a bachelor's degree in marine engineering systems from the United States Merchant Marine Academy and a master's degree in business from New York University.

Posted from Plant Engineering, November 2008. Copyright © Reed Business Information, a division of Reed Elsevier, Inc. All rights reserved.
Page layout as originally published in Plant Engineering has been modified.
#1-25476791 Managed by The YGS Group, 717.399.1900. For more information visit www.theYGSgroup.com/reprints.

For Single Print Only



AERCO INTERNATIONAL, INC.
159 PARIS AVENUE • NORTHVALE, NJ 07647
(201) 768-2400 • Fax: (201) 768-7789
info@aerco.com • www. aerco.com

Energy Savings Report
ECM # 3 Lighting Upgrade

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	Throughout entire building
Product or Process:	Lighting upgrade
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Michael Phillips, Project Manager

Tozour Energy Services
THE POWER TO SAVE

Project Scope Definition

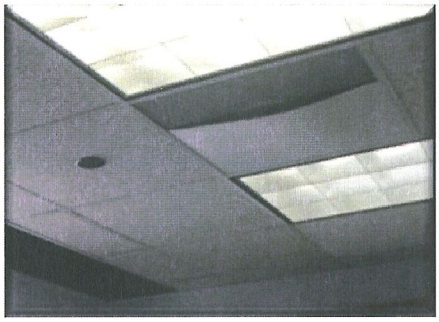
Project consists of retrofit or replacement of 537 existing light fixtures and 48 occupancy sensors and photocells with all associated electrical work.

Every effort has been made to standardize the installed components to reduce operational and maintenance costs over the life of the installed system. Energy savings calculations are based upon hours of operation for each area surveyed. These hours are determined through a combination of information obtained from the energy audit as well as commonly accepted industry standards. Ballast wattages presented within the energy savings analysis are based upon the manufacturers' reported technical data.

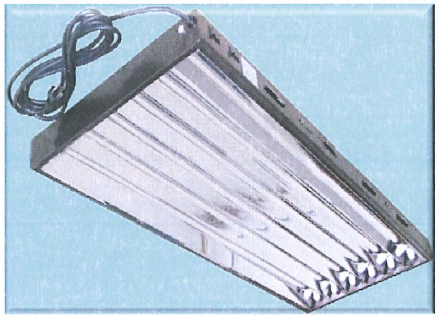
This project will retrofit the existing lighting system with newer technology energy efficient lamps, ballasts, and light fixtures. The lighting retrofit design incorporates the replacement of lamps and ballasts as well as the replacement of light fixtures when the fixture is in poor condition.

Areas of the Facility to be retrofitted with new lamps & ballasts include: Office areas, Court rooms, Storage, Police interior, Staff lounges, & Corridors

Existing Conditions & Planned Improvements



Existing T12 fluorescent lights



T-8 fluorescent lights



Compact fluorescent lights

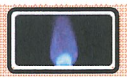
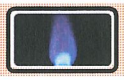
The main building and Police headquarters are lighted by a combination of T12 fluorescent fixtures, 100 Watt mercury vapor fixtures and incandescent bulbs. The lighting on the Police side are on 24 hours per day, 7 days per week. The main building side lighting is on approximately 50 hours per week. The lighting upgrade includes a combination of T-8 and compact fluorescent lights and new fixtures.

Energy Savings Report
ECM # 3 Lighting Upgrade

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	Throughout entire building
Product or Process:	Lighting upgrade
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Michael Phillips, Project Manager

Tozour Energy Services
THE POWER TO SAVE

Cost & Savings Analysis - Savings calculated by the Trace 700 building model simulation program

	Installation Cost	$44,200	
	Reduction in Electric Consumption	121,419	kWh
	Reduction in Electric Demand	18	kW
	Reduction in Natural Gas	-97	dTh
	Electrical Consumption Cost	$0.1645	/ kWh
	Electrical Demand Cost	$0.00	/ kW
	Natural Gas Cost	$12.29	/ dTh
	Annual Energy Savings	$18,782	
	Annual Operational Savings	$0	
	Annual Total Savings	$18,782	
	Pay for Performance Incentive	$24,297	
	Simple Payback - No Incentive	2.4	Years
	Simple Payback with P4P Incentive	1.1	Years
	Reduction in CO_2	86	Tons
	Equivalent Additional Trees	431	Trees
	Equivalent Reduction in Automobiles	15	Cars

Presented By:	**Tozour Energy Systems**		
Contact Phone:	484 6788924	Customer Name:	Malapan Township
		Project Name:	SAMPLE
Contact E-mail:	kkeenan@tozourenergy.com	Fixture Type:	SAMPLE

GE Lighting

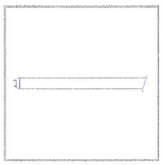
45741 - F17T8/SP30/ECO

GE Ecolux® Starcoat® T8

- Passes TCLP, which can lower disposal costs.

High Color Rendering







CAUTIONS & WARNINGS

Caution

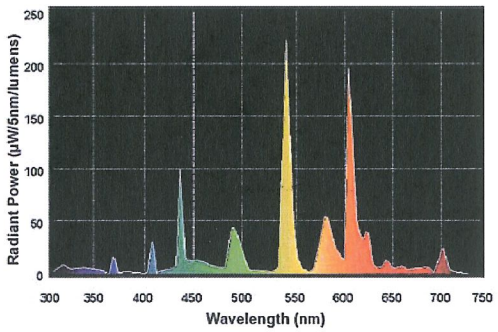
- Lamp may shatter and cause injury if broken
  - Wear safety glasses and gloves when handling lamp.
  - Do not use excessive force when installing lamp.

Warning

- Risk of Electric Shock
  - Turn power off before inspection, installation or removal.

GRAPHS & CHARTS

Spectral Power Distribution



Lumen Maintenance

GENERAL CHARACTERISTICS

Lamp Type	Linear Fluorescent - Straight Linear
Bulb	T8
Base	Medium Bi-Pin (G13)
Wattage	17
Voltage	70
Rated Life	20000 hrs
Rated Life (instant start) @ Time	15000 h @ 3 h 20000 h @ 12 h
Rated Life (rapid start) @ Time	20000.0 @ 3.0/24000.0 @ 12.0 h
Bulb Material	Soda lime
Starting Temperature	10 K (50 °F)
LEED-EB MR Credit	157 picograms Hg per mean lumen hour
Additional Info	TCLP compliant

PHOTOMETRIC CHARACTERISTICS

Initial Lumens	1325
Mean Lumens	1260
Nominal Initial Lumens per Watt	77
Color Temperature	3000 K
Color Rendering Index (CRI)	78
S/P Ratio (Scotopic/Photopic Ratio)	1.3

ELECTRICAL CHARACTERISTICS

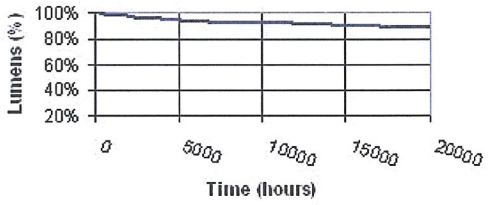
Open Circuit Voltage (rapid start)	285 V
Open Circuit Voltage (rapid start) Min @ Temperature	210 V @ 10 °C
Cathode Resistance Ratio - Rh/Rc (MIN)	4.25
Cathode Resistance Ratio - Rh/Rc (MAX)	6.5
Current Crest Factor	1.7

DIMENSIONS

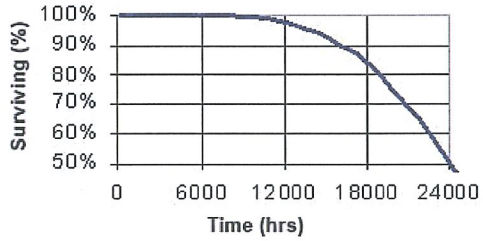
Maximum Overall Length (MOL)	23.78 cm
Minimum Overall Length	23.67 cm
Nominal Length	24 cm
Bulb Diameter (DIA)	1 cm
Bulb Diameter (DIA) (MIN)	0.94 cm
Bulb Diameter (DIA) (MAX)	1 cm
Max Base Face to Base Face (A)	23.22 cm
Face to End of Opposing Pin (B) (MIN)	23.4 cm
Face to End of Opposing Pin (B) (MAX)	23.5 cm
End of Base Pin to End of Opposite Pin End (C)	23.67 cm

PRODUCT INFORMATION

Product Code	45741
Description	F17T8/SP30/ECO
ANSI Code	1001-1
Standard Package	Case
Standard Package GTIN	10043168457412
Standard Package Quantity	24
Sales Unit	Unit
No Of Items Per Sales Unit	1
No Of Items Per Standard Package	24
UPC	043168457415



Lamp Mortality



LevitonProducts.com
877-TWAcomm
877-389-0000
V: 714-536-4550
F: 714-960-8095

Leviton Wall Mount Multi-Tech Wide View Occupancy

(Model # OSW12-M0W)



$143.26

Availability:
Usually ships in 5 days

Options

NAFTA Compliant
· Yes
· No

Manufacturer
5 Yr. Warranty

Similar Products

- Fluorescent Energy Management System
- Wall Mount Occupancy Sensors

More Products from **Leviton**

Multi-Technology, 110 Degree, 1200 Sq. Ft.Coverage, Self-Adjusting, Wall Mount Occupancy Sensor, Commercial Grade - White

Features:

- The sensor provides a trouble-free "install and forget" solution for lighting control
- Self-adjusting settings continuously analyze and adjust infrared sensitivity, timer operation, and long term performance
- Adjustable swivel neck rotates 80 degrees vertically and 60 degrees horizontally. Can be used for ceiling or wall mounting

- Ambient light override prevents lights from turning on when there is ample natural light
- Self-Adjusting delayed-off time interval settings for 30 seconds to 30 minutes. Compensates for real-time occupancy patterns- preventing unnecessary on/off switching
- Non-volitile memory preserves all automatic and manual settings during power outages
- Fast, simple installation using 3 color-coded low-voltage wires and a single mounting post

Print Window | Close Window

To return to this product type the following URL in your browser's address bar:
http://www.levitonproducts.com/catalog/model_OSW12-M0W.htm
12/02/2010 12:47:07

Energy Savings Report

ECM # 4 Controls Upgrade

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	Chiller, Boilers, Pumps, Air handlers & VAV boxes
Product or Process:	Building Automation System (BAS) upgrade
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Jeff Norton, CEM, Sales Engineer

Tozour Energy Services
THE POWER TO SAVE

Project Scope Definition

The controls upgrade includes a new supervisory network allowing a web based single seat user interface for the building. The system is easily expandable to include future sites. Modern Direct Digital Controls (DDC) controls are inherently more accurate and precise enabling the elimination of energy waste for both air side systems as well as central plant. A newer, more robust control system allows creative sequences enabling equipment to run optimized and more efficiently. Our DDC controls systems are available with energy dashboards that track usage and trends of site energy. This information is invaluable in maintaining a facility after controls, sequences and equipment have been upgraded. This upgrade includes new control boards, damper actuators, and hot water valves for 57 VAV boxes. Wireless thermostats will be used to reduce installation costs.

Tozour Energy Systems employs an in-house Sustainability Services Center (SSC) in conjunction with the controls and energy dashboard to monitor the comfort, efficiency and energy usage of all equipment in the facility. Regular building report cards show the ongoing efficiency (Constant Commissioning) and alert staff to and impending problems, equipment failure, or energy wasting circumstances early in the process before something becomes a major issue. SSC eliminates the "rearview mirror" strategy for dealing with building problems and inefficiencies.

As controls are upgraded and mechanical systems improved the opportunity to Retro-Commission (RCx) the equipment is readily available. RCx is a process that identifies and repairs all the non-capital (i.e.; process-driven) functions to reduce the site's energy consumption. Non-capital savings consists of ECMs that typically provide paybacks of less than 18 months and don't require major equipment replacements. RCx will focus on making adjustments to the mechanical systems to optimize time of day scheduling, economizer (free cooling), temperature resets, and sequence of operation. RCx is used to eliminate simultaneous heating and cooling and ensures proper calibration of individual components to make overall system operations improved.

Demand Control Ventilation (DCV) is a control sequence of operations designed to save energy by optimizing the amount of outdoor air brought into the facility. A DCV strategy typically is set up to monitor the occupancy of an area by measuring the level of CO2 in that area. As the CO2 level rises, the DDC control system will accordingly increase the amount of outdoor air introduced to the area. When areas are only slightly occupied or completely unoccupied, less outdoor air in brought in by the HVAC system. This allows energy savings by reducing the amount of warm air needing to be cooled or cold air needing to be heated.

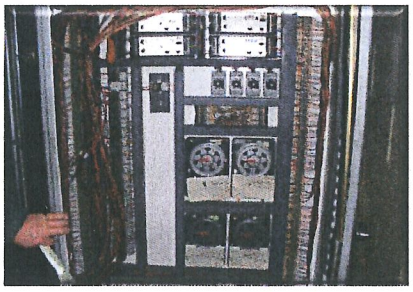
Temperature Reset is a control strategy for air or water that adjusts the temperature depending on other conditions. Air handling units supply temperature can be reset dependent on outdoor or building temperature. The boiler system heating hot water temperature can be reset most effectively to save energy using outdoor air temperature. As outdoor temperature increases, the boiler set point temperature decreases. A typical scale in many office environments is when outdoor temp = 0°, hot water temp = 180°, when outdoor temp reaches 60°, hot water temp is reduced to 120°. Above 60° outdoor temp the boiler is normally disabled.

Energy Savings Report
ECM # 4 Controls Upgrade

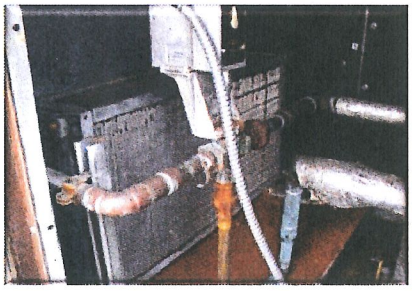
Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	Chiller, Boilers, Pumps, Air handlers & VAV boxes
Product or Process:	Building Automation System (BAS) upgrade
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Jeff Norton, CEM, Sales Engineer

Tozour Energy Services
THE POWER TO SAVE

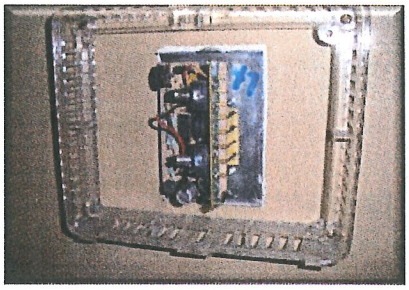
Existing Conditions & Planned Improvements



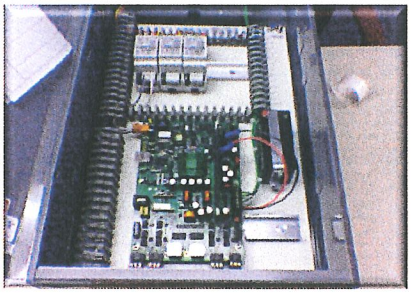
Existing controls system



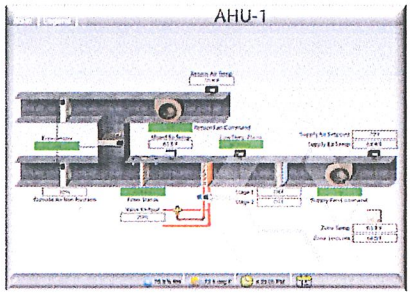
Existing controls valve



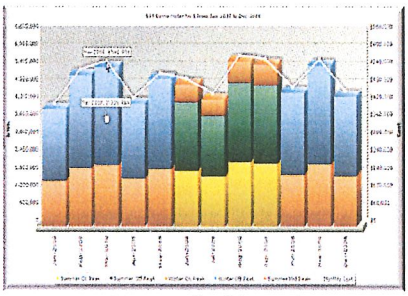
Existing VAV box thermostat



Modern controls



Animated graphics



Energy dashboard

The controls upgrade project includes a total controls retrofit including control boards for all VAV boxes. AHU chilled water & hot water valves. Though calculations do not show large energy & cost savings values directly associated with this line item, it is important to realize that this energy conservation measure (ECM) is key to the savings of several of the other ECMs. It would not be possible to optimize savings for the chiller, boiler, or air handler upgrades without this upgrade to the controls system.

Energy Savings Report

ECM # 4 Controls Upgrade

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	Chiller, Boilers, Pumps, Air handlers & VAV boxes
Product or Process:	Building Automation System (BAS) upgrade
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Jeff Norton, CEM, Sales Engineer

Tozour Energy Services
THE POWER TO SAVE

Cost & Savings Analysis - Savings calculated by the Trace 700 building model simulation program

Installation Cost	$168,763	
Reduction in Electric Consumption	60,706	kWh
Reduction in Electric Demand	5	kW
Reduction in Natural Gas	216	dTh
Electrical Consumption Cost	$0.1645	/ kWh
Electrical Demand Cost	$0.00	/ kW
Natural Gas Cost	$12.29	/ dTh
Annual Energy Savings	$12,636	
Annual Operational Savings	$0	
Annual Total Savings	$12,636	
Pay for Performance Incentive	$0	
Simple Payback - No Incentive	13.4	Years
Simple Payback with P4P Incentive	N/A	Years
Reduction in CO_2	56	Tons
Equivalent Additional Trees	282	Trees
Equivalent Reduction in Automobiles	10	Cars

Tozour-Trane

HIGH PERFORMANCE BUILDINGS FOR LIFE™

306 Horizon Drive
King of Prussia, PA 19406
P: 610.962.1600 F: 610.962.0230

www.tozourenergysystems.com



BACnet www.bacnet.org

Solution Provided: We are well-versed in the integration of various products that use BACnet. BACnet is a data communications protocol for **B**uilding **A**utomation and **C**ontrol **Net**works.

Building Logix www.buildinglogix.net

Solution Provided: Our Building Logix partner, powered by Niagara, delivers open integration products and special applications to deliver the power of the Internet combined with the ultimate in web services. These services include operational dashboards and system diagnostics as well as predictive modeling for maximum equipment and building performance.

Distech Controls www.distech-controls.com

Solution Provided: Distech Controls manufactures open and scalable building automation products, promoting an energy efficient and environmental design of buildings worldwide. Our intuitive and innovative solutions provide for optimized energy management strategies and reduced building automation systems' lifecycle cost.

EFT Control Systems www.eft.ie

Solution Provided: EFT is a company specializing in automation and process control. They utilize a deep understanding about industrial operations and data capture with highly skilled software developers in EFT Control Systems. This ultimately led to the development of what is today the clear market-leading energy management solution. This enables EFT Control Systems to provide its clients with a turnkey energy management solution that has been developed around real customer requirements.

LonMark International www.lonmark.org

Solution Provided: We are well-versed in the integration of various products that use LON. LonMark International is a global membership organization created to promote and advance the business of efficient and effective integration of open, multi-vendor control systems utilizing ISO/IEC 14908-1 and related standards. ISO/IEC have approved the LonWorks platform to the highest level of international standards recognition.

Trane www.trane.com

Solution Provided: Trane controls are the keystone to making a building work better for life. They are engineered to be user-friendly and help building owners efficiently achieve their desired temperature, humidity and ventilation, whatever the building's purpose.

Tridium Niagara^{AX} www.tridium.com

Solution Provided: Niagara^{AX} is a software framework specifically designed to address the challenges of building device-to-enterprise applications, Internet-enabled products and Internet-based automation systems. Niagara^{AX} provides a unified, feature-rich platform that streamlines the development process, significantly reducing implementation costs and time to market. Niagara^{AX} creates a common environment that connects to almost any embedded device imaginable, regardless of manufacturer or communication protocol. Niagara^{AX} models the data and behavior of the devices into normalized software components, providing a seamless, uniform view of device data to the enterprise via a wide variety of IP-based protocols, XML-based connectivity options, and open API's.

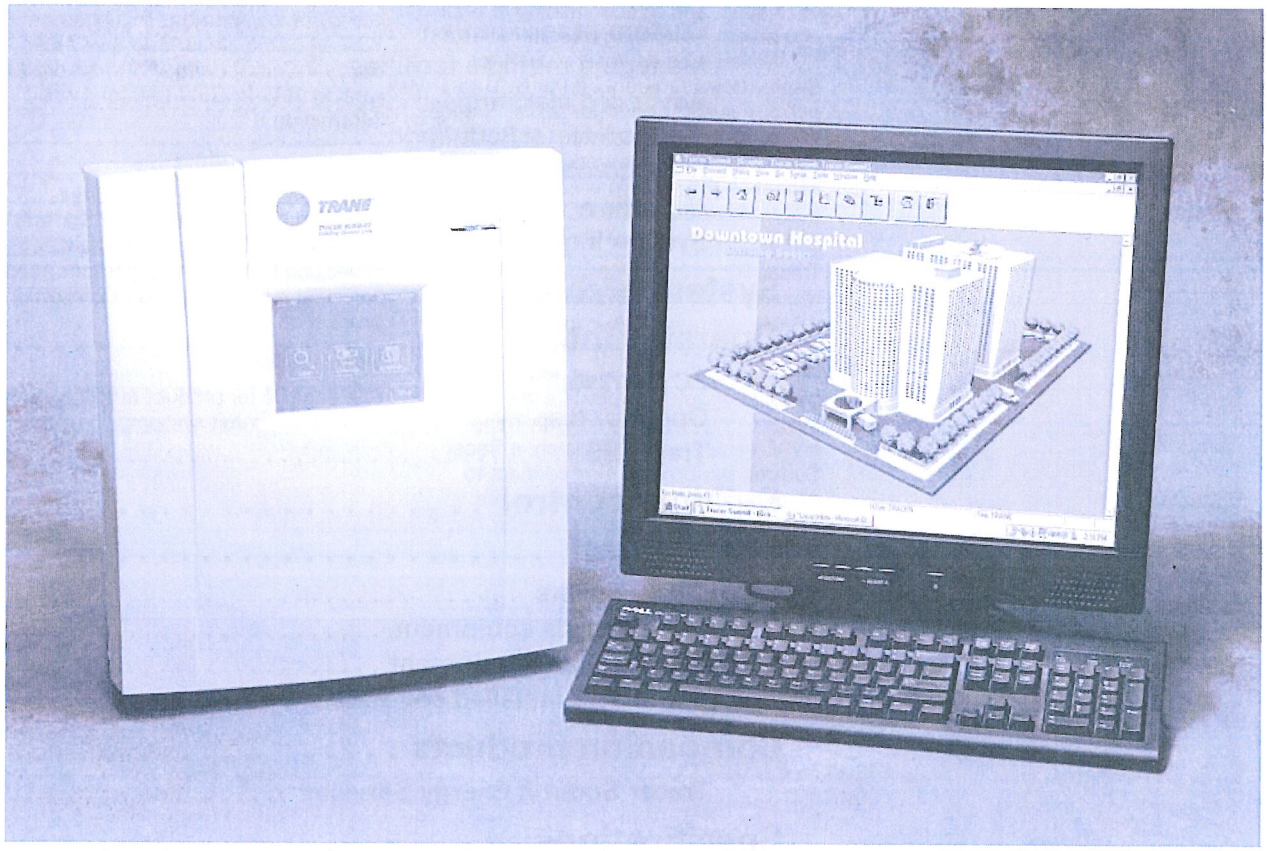
Ywire Technologies Inc. www.ywiretech.com

Solution Provided: YWire has become the first manufacturer to implement Broadband over Power Line (BPL) data networks into building systems. Founded by three highly experienced industry professionals, YWire is able to view the building controls market from unconventional perspectives—which has ushered in new technologies to a mature community. YWire is also the first to implement IP connectivity at the device level, truly a major milestone in the evolution of intelligent devices connected to the smart grid.

TRANE

Tracer Summit™

Building Automation System



November 2009

BAS-PRC001-EN

Ease of service

The optional Rover service tool can be launched from Tracer Summit software to identify problems, test functionality, change configuration, create and edit programming, and monitor status information for LonTalk unit controllers on the system. From an operator on site, to a technician several miles away using a remote connection, the combination of Tracer Summit software and a Rover service tool provide the data and functionality required to fully and conveniently service the building automation system.

Chiller plant control

The Tracer Summit chiller plant control application provides intelligent control and comprehensive monitoring of system components, including:

- Multiple chillers
- Related pumps and valves
- Cooling towers and ice tanks

The chiller plant control application balances system efficiency and equipment runtime to optimize system performance.

The application also provides status information that can help with troubleshooting. The status information indicates what is happening in the chiller plant as well as what to expect next, based on current operating conditions.

The chiller plant control program is suitable for both comfort and industrial applications, as well as control sequences including thermal storage and dual-fuel chiller systems.

Area control

Area control coordinates HVAC equipment and lighting for a specific area of the building.

Unit controllers and binary outputs are assigned as members of a common area, which makes it easy to change setpoints, do scheduling, and perform overrides at the PC Workstation.

Trend Viewer

The Trend Viewer (see Figure 2) allows the user to track data over time; to overlay alarms, events, and overrides; and to collect trended data that spans long time periods. Trend data is stored on a database on the PC Workstation.

Note: The PC Workstation must be online and connected to the BCU to capture continuous data from the BCU. The BCU temporarily caches trended values, so if a connection is lost for a short amount of time, no gaps will be seen in the data.

Timed override

As a part of the Area Control application, the timed override feature enables building occupants and management staff to temporarily override HVAC and lighting equipment.

Users can perform overrides from the zone sensor, the BCU operator display, the Tracer Summit PC Workstation software, or Tracer ES.

Variable-air-volume air system (VAS)

The Tracer Summit variable-air-volume air system (VAS) control coordinates air-handling units and VAV boxes within a building. VAV units are assigned to the air-handling unit that supplies air to them. A VAS control starts up and shuts down the system to assure proper static pressure control. Energy-saving applications, including static pressure optimization and ventilation optimization, are available as standard VAS control features for LonTalk systems.

Indoor air quality control

Indoor air quality is an issue of rising importance from the perspectives of comfort as well as governmental regulation and liability. A Tracer Summit system intelligently monitors indoor air quality to make maintaining it easy.

When used in conjunction with Trane Traq dampers, Tracer Summit software can adjust the intake of outdoor air to ensure compliance with ASHRAE standards.

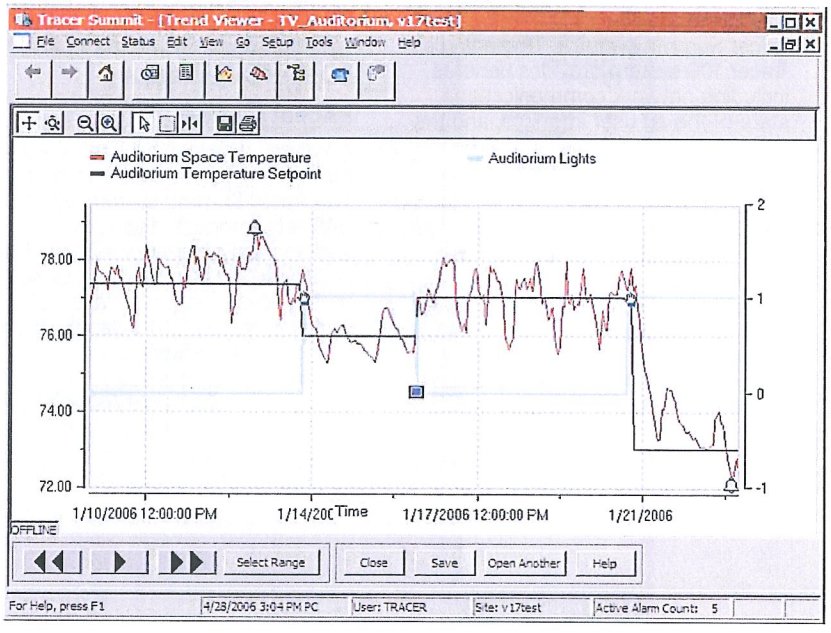
Custom programming

A powerful custom programming language (CPL) allows system customizing for specific applications. Typically, CPL routines are created to sequence equipment, calculate setpoints and values, and perform shutdown sequences.

Managing multiple facilities

To assist in managing multiple facility locations, the Tracer Summit Enterprise Management Package includes utilities that help the daily operator work more

Figure 2. Trend Viewer



Operator interface

Operators have four interface options for managing their building automation systems:

- PC Workstation
- Operator display
- Tracer ES

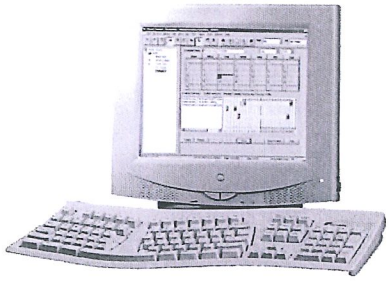
PC Workstation

The Tracer Summit PC Workstation software provides a graphical user interface for setting up, operating, and modifying the building automation system. This interface along with the use of Microsoft Windows and Internet Explorer make building operation as easy as surfing the World Wide Web.

Tracer Summit PC Workstation software can be run on a PC located at the building site or from a remote location. The software can also be used to connect to and monitor operations for multiple building sites. For example, a user can view the status of a chiller located in the next room, while modifying the schedule for a building that is across the city or around the world.

Tracer Summit PC Workstation software runs with Microsoft Windows Vista Business or Windows XP Professional operating systems. Operating with Windows offers the flexibility of running other popular applications for communications and office productivity. See *Hardware requirements* on page 15 for more PC Workstation details.

The Tracer Summit PC Workstation is the most common interface for accessing building automation systems. The primary features are described in this section.



Alarm processing and event log

The daily operator must be able to deal effectively with abnormal conditions. When the system detects such a condition, it routes the alarm to the appropriate PC Workstation(s), pagers, cell phones, and e-mail addresses.

At the PC Workstation, alarms and other system events are stored in the alarm and event log. The alarm and event log have five optional, configurable alarm categories that can be used to filter and sort the alarms. Sorting can be based, for example, on severity level.

If another application is in use when an abnormal condition occurs, an alarm is indicated in the task bar at the bottom of the screen. Pop-up messages can also be associated with alarms, to alert the user of the abnormal condition.

The event log displays critical data about the alarm including which building it is from, whether it requires an acknowledgment, and any comments that may have been entered in the pop-up dialog box.

Critical alarms can be set up with messages and graphics that can aid in troubleshooting problems.

A series of easy-to-use filters can be used to show only desired events: For example, a filter can be used to view alarms only from a specific building, to view alarms received only at a specific time, or only alarms from a specific alarm category.

Graphics

Tracer Summit software uses graphics as a means of viewing and navigating through the system, much like walking through the building. Graphics show data related to building environments, including climate, lighting, and other controllable operations. Graphics can be used to change setpoints and override equipment operation.

Putting graphics in groups makes it possible to move logically from place to place within a building. Target buttons can be added to graphics to provide links to related sources.

The navigation tree—a hierarchical, tree-style representation showing the relationship of all graphics for a facility (see Figure 1 on page 4)—provides a way to move between graphics and buildings. The navigation tree is a standard part of every system and can be easily modified.

Forward, Back, and Home buttons on the menu bar provide another way to move among graphics.

Graphics library and graphics editing

A library of standard graphics representing all Trane equipment and applications is included in the Tracer Summit software. In addition, standard 3D graphics provide a better visual representation of equipment along with relevant equipment information. These standard graphics have been tested to provide a consistently high level of quality and usability.

Custom graphics can also be created by incorporating visual elements from the building, such as floor plans or exterior views from CAD drawings, into standard graphics. Custom graphics can also include digital photography and animated images such as a rotating fan.

Graphics can include the following elements:

- Any data available in the system as a numerical or text value
- Analog values that can change colors based on deviation from a desired value for quick recognition of operational issues
- User-defined static text in a wide choice of fonts and colors
- Animation using images to represent binary and analog values, animated GIF, or video (AVI) files
- Hyperlinked text and images that can be added to move between graphics
- Hyperlinks to any Windows-compatible files or applications (for example, Adobe Acrobat documents, Excel spreadsheets, and external Web sites)
- Multiple graphic images that conform to the industry standard JPEG, GIF, or BMP formats, in addition to the library of HVAC equipment images included with the Tracer Summit software package

Unit control

The Tracer Summit system provides centralized control for Trane HVAC and other unit-level equipment. Tracer Summit software supports the following Trane equipment:

Trane chillers

- CenTraVac chiller with a UCP2 or a Tracer CH530 chiller controller
- Series R CenTraVac chiller with a UCP2 or a Tracer CH530 chiller controller
- Scroll chiller with an IntelliPak, classic, or Scroll Manager Module (SMM) controller
- Absorption chillers with a UCP2, classic, or Horizon controller
- Series R air-cooled and water-cooled chillers

Trane airside equipment

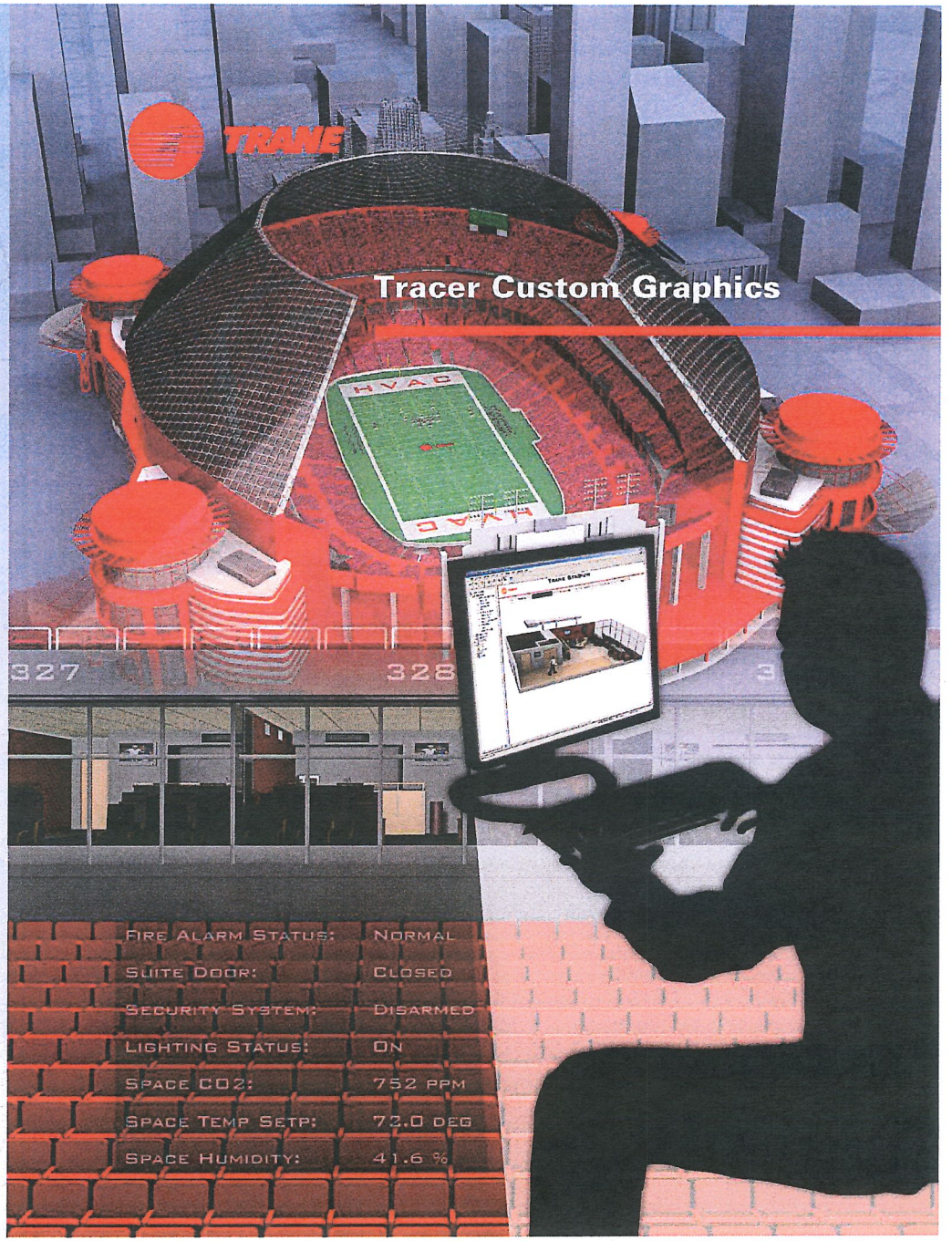
- VariTrane with a Trane variable-air-volume controller (VAV I, II, III, and IV) or Tracer VV550 VAV controller
- VariTrac II changeover VAV system
- Fan coil with a Trane terminal unit controller (TUC) or Tracer ZN510 or ZN520 controller
- Classroom unit ventilator with a Trane terminal unit controller (TUC) or Tracer ZN520 controller
- Air handler with a PCM, UPCM, Tracer MP580, or Tracer AH540 controller

Trane unitary equipment

- Voyager rooftop air-conditioning unit
- IntelliPak air-conditioning units
- Water-source heat pump with a Trane terminal unit controller (TUC), Tracer ZN510 controller, or Tracer ZN524 controller
- Precedent rooftop air-conditioning units with ReliaTel controls

Trane field-installed controllers

- Programmable control module (PCM)
- Universal programmable control module (UPCM)
- Thermostat control module (TCM)
- Trane terminal unit controller (TUC)
- Tracer loop controller
- Tracer MP581 programmable controller
- Tracer MP501 multi-purpose controller
- Tracer MP503 input/output module
- Tracer ZN511 zone controller
- Tracer ZN517 zone controller
- Tracer ZN521 zone controller
- Tracer ZN523 zone controller
- Tracer ZN524 zone controller
- Tracer AH541 air-handler controller
- Tracer VV551 VAV controller
- Tracer CH531 chiller controller



Tracer Custom Graphics

TRANE

Trane
A business of American Standard Companies
www.trane.com

For more information, contact your local Trane office or http:// www.trane.com

Literature Order Number	BAS-SLB022-EN
Date	November 2006
Supersedes	New

Trane has a policy of continuous product and product data improvement and reserves the right to change design and specifications without notice.

TRANE

How do you want to see your facility?

A Tracer™ building automation system becomes a window into a facility professional's prime mission: managing the facility or portfolio of buildings they are responsible for. Trane systems and interfaces provide a number of ways to view and control building data.

Customers can select from two options for the style graphics provided with a turnkey BAS project:

2-dimensional (2D)
3-dimensional (3D)

3D graphics provide an added dimension of realism and help operating staff visualize their actual facility.

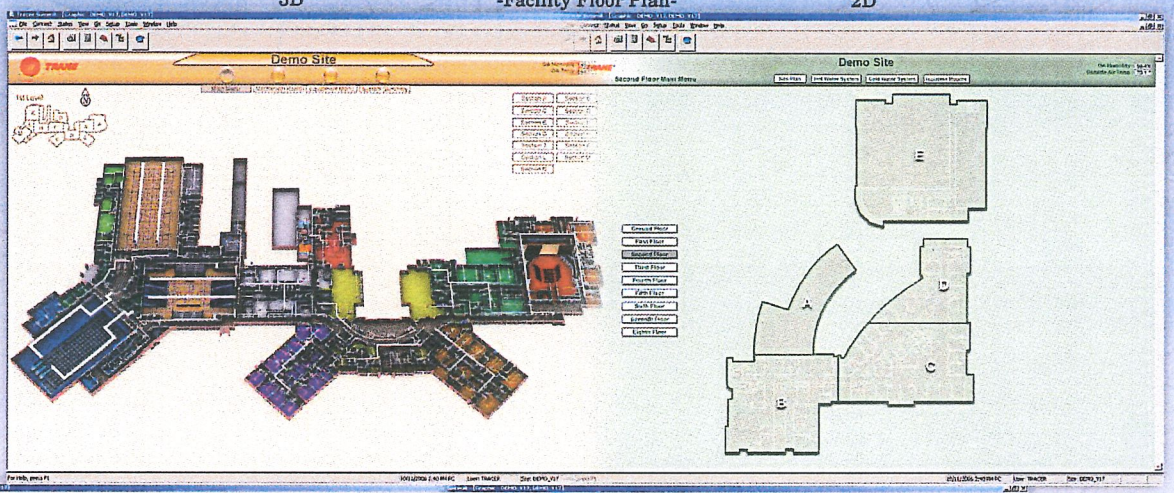
Contact your local Trane office to find out more information about the best way to see your facility.

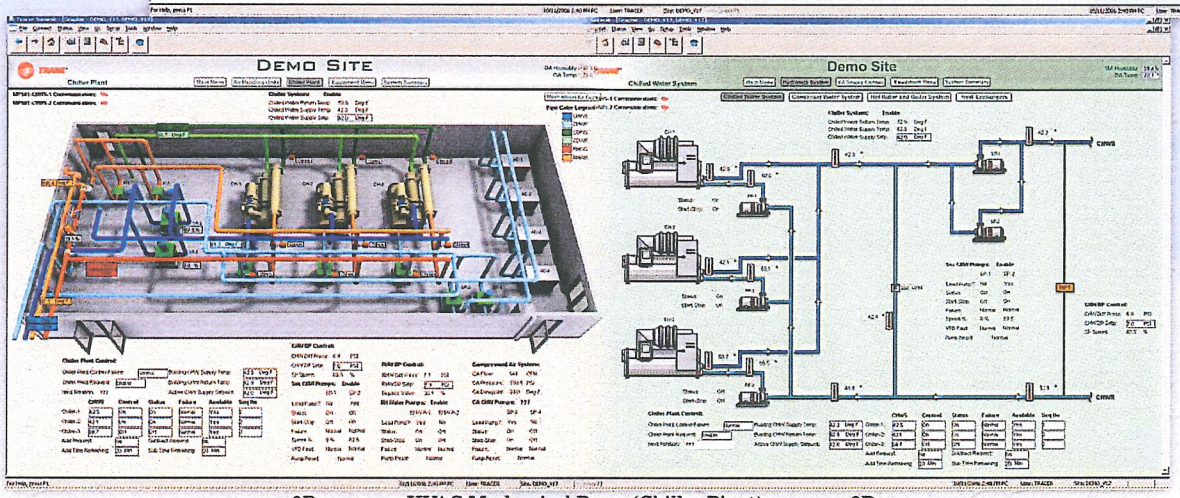
"Graphics help our staff quickly grasp what's happening in the systems and spaces."

Type of Graphic	**Standard Project**	**Upgraded Graphics** (3D)
Building exterior	None	3D
Floor plan	2D	3D
Tenant space or room	2D	3D
Mechanical room	2D	3D
HVAC unit(s)	3D*	3D

*3D graphics of equipment are included in standard projects.

3D -Facility Floor Plan- 2D





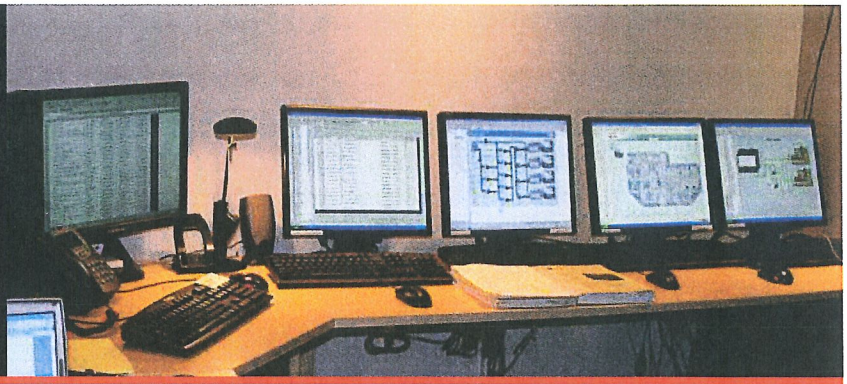
3D -HVAC Mechanical Room (Chiller Plant)- 2D

Tozour-Trane

HIGH PERFORMANCE BUILDINGS FOR LIFE™

3606 Horizon Drive
King of Prussia, PA 19406
P: 610.962.1600 F: 610.962.0230

www.tozourenergysystems.com



What are Sustainability Services?

Sustainability Services is Tozour-Trane interacting with your facility remotely. We will monitor alarms and critical situations, as well as gather pertinent data to deliver custom reports with the information you need to know. Sustainability Services will help you save time and money, through lower energy costs, reduced down-time, and efficiently planned maintenance. Sustanability Services will also help reduce the risk of major equipment failures.

Alarm Monitoring & Tracer Summit Support

Don't have time to constantly monitor your Facility Management System? Your Tracer Summit System can report alarms directly to our Sustainability Services Center. Our experienced professionals will contact you or deal with the situation as needed per our agreement. Have some peace of mind knowing we are keeping watch. We are also available for Tracer Summit support on an as needed basis. This service is available 24/7/365.

System Diagnostics & Reporting

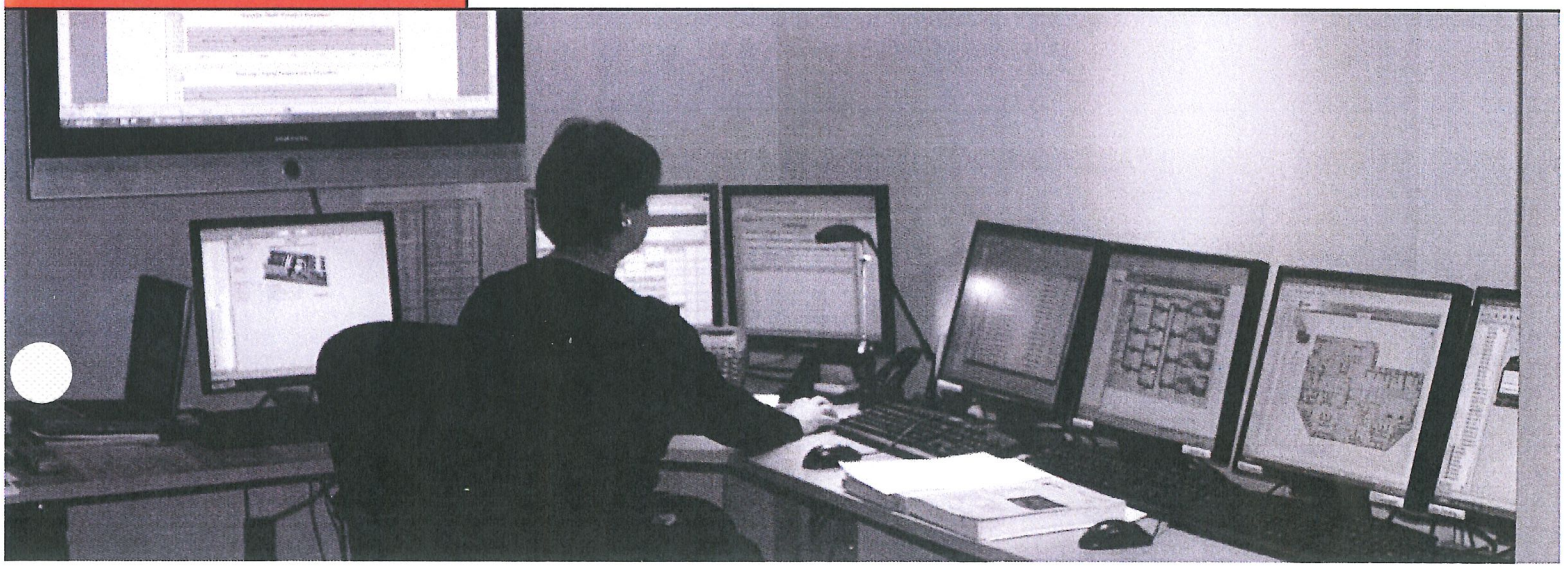
Did you know we remotely perform control loop and diagnostic tests on a building's HVAC system? Tozour-Trane will provide you with the information you need to direct and schedule your maintenance activities. Let our custom reporting guide your resources where and when they are needed. We can perform regular scheduled service and detailed analysis to improve efficiencies, help correct problems, and maintain your building systems as they were commissioned.

HVAC Performance Monitoring

What if at a glance you could tell how your entire facility and all of your systems are performing? We will create reports that will instantly show how well your HVAC systems are working. Performance Monitoring reports show in simple fashion how well the building and each system are doing on a scale from 0 to 10 (10 being perfect operation). Performance Monitoring will help you to find deteriorating conditions before they become critical issues. It will also show immediately if repairs done on equipment were diagnosed and executed efficiently.

Energy Services

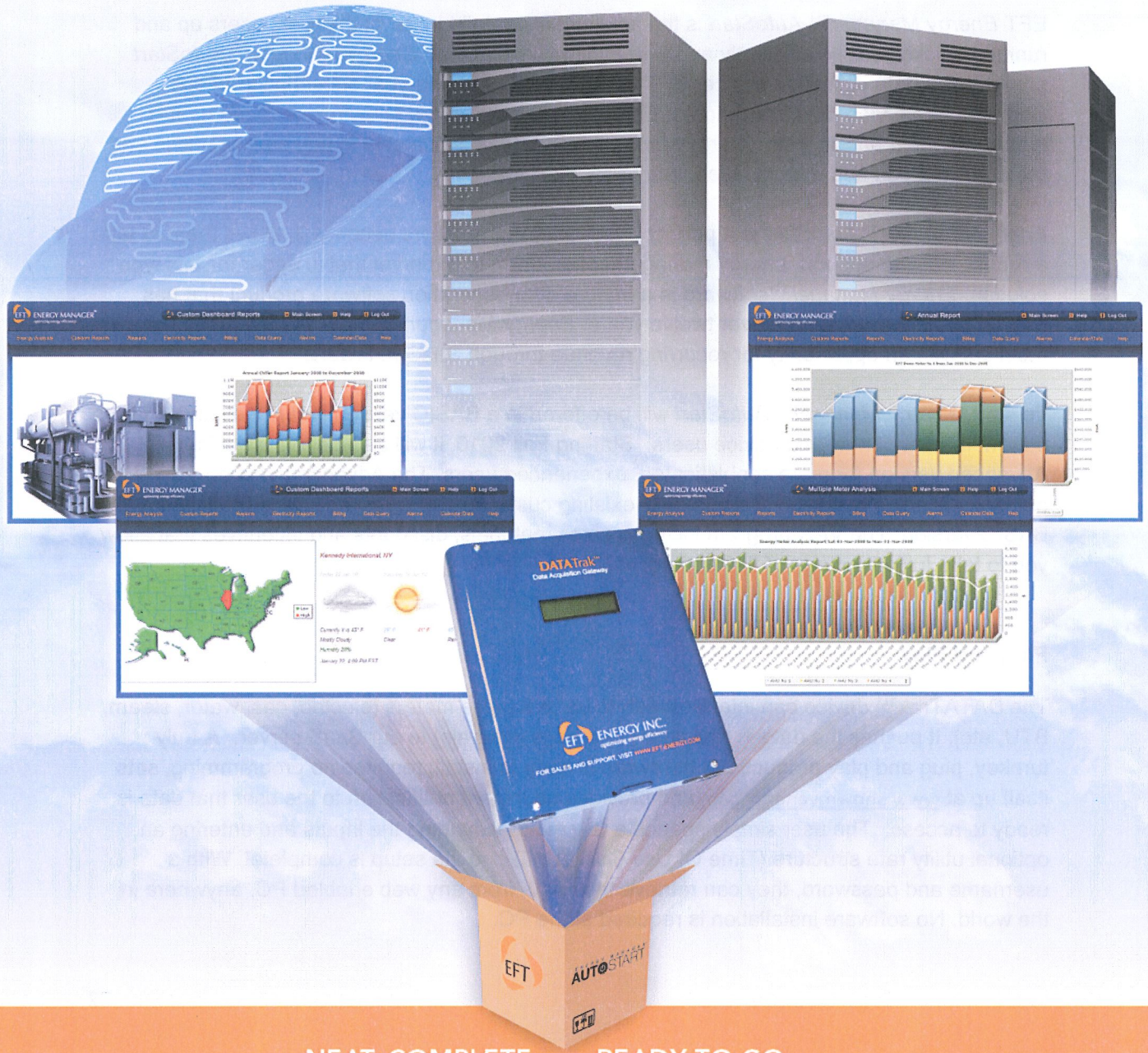
Tozour-Trane has tools to help you monitor, manage, and save energy in your facility. HVAC and lighting are the largest energy cost factors in nearly all facilities. Let us use our products and building expertise to find ways to positively impact your budget.



EFT ENERGY INC.
optimizing energy efficiency

ENERGY MANAGER™ AUTOSTART

Value Added Reseller (VAR) Program



NEAT, COMPLETE READY TO GO

Customer Benefits

The goal of this product is to provide our VARs and their customers with a cost effective, easy to install, yet powerful energy management product. Think of it as an energy management starter kit. Perfectly suited to the new and novice user markets, with upgrades available (Fall 2010) for advanced users, it offers skill appropriate levels of energy reporting together with data collection, data storage and data management. Customer benefits include:

- No need for a large capital investment
- Basic version is a great introduction to energy management analysis and tools
- Facilitates instant productivity. Set up is minimal and quick. Reports are easy to access and very easy to use. Customers do not have to spend time collecting, organizing or managing data. www.showmyenergy.com handles these tasks
- Little user training required for the Basic version
- Advanced version has features and functionality that will satisfy even the most savvy energy manager (Available Fall 2010).

Easy Scalability

For customers who want to add more points to the system, we provide an easy solution. They simply contact their VAR to purchase additional DATATraks. The newly installed points will be added to their *Energy Manager™ AutoStart* User Account at www.showmyenergy.com. Customers can add at any time, at their own pace. VARs can also provide a natural migration from the Basic Version to the Advanced Version, once users have proficiency (at least three months experience) with the Basic Version.

Advanced Version (Available Fall 2010)

For more experienced users, EFT will offer *Energy Manager™ AutoStart* Advanced (estimated release date Fall 2010). This version presents the full power of *Energy Manager ™* with advanced reporting, completely customizable reports and dashboards, and added features like tenant invoicing and data query. The Advanced version requires a higher level of support services so we are encouraging customers to spend three (3) months with the Basic version to minimize the learning curve. We also recommend that our VARs include extra support hours in their Advanced packages.

Timing is everything and the timing for this product is now!

Combine easy to install data acquisition hardware with a potent energy management application and recurring revenues and what do you get? A product that the market is asking for, a product that lets them "put a toe in the water" in energy management without breaking the bank, and most important, a product they don't see in the market today, in other words… a major sales opportunity for you!

Activation Process

VAR Stock. Once *Energy Manager™ AutoStart* is shipped to the end customer, please email us the device serial number and the email address that we should use when sending log in information. Email address can be the end user or VAR service person. Send email/serial number to support@eft-energy.com. Serial numbers can be found on the outside of the shipping box and inside of the DATATrak™ device (See DATATrak Installation Guide for details). Log in information will be sent to user after the unit is installed and begins sending data back to www.showmyenergy.com.

New orders. If placing a Purchase Order to EFT for *Energy Manager™ AutoStart,* please provide the email address that we should use when sending log in information.

VAR Program

Incentives & Support

- EFT will provide VAR's staff with ongoing support to help them service the end customer
- EFT offers a distributor discount.
- EFT provide sales materials that VAR can distribute to their end customer
- EFT provides VAR the option of branding www.showmyenergy.com with VAR's logo and contact information.
- SaaS program represents recurring revenues for VAR.

VAR Eligibility & Responsibilities

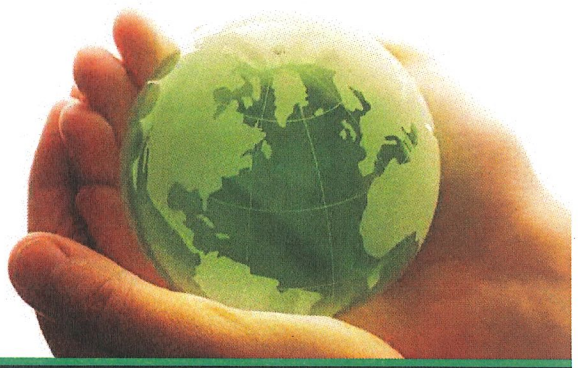
- EFT's goal is to allow the VAR to maintain their relationship with their customer. Therefore, we would like the VAR to be responsible for being the key contact and service provider for the end customer. This includes handling first tier support and maintaining customer relationships. VAR should:
    - Provide the service of installing the DATATrak™ or providing support to the installer (building's electrician or qualified technician)
    - Provide user start up support, including initial set up of user account (naming meter inputs and entering TOU rate structures)
- VAR to email EFT with information for product activation (DATATrak™ serial number and email address). VAR to email EFT of any changes in ID email address
- EFT requests that VAR sell BASIC version to new customers with the requirement that user accumulate a minimum three (3) months experience before upgrading to Advanced version (available Fall 2010). This is in the best interest of both the user and VAR since it will ensure immediate productivity by user, minimal training and support by VAR, and sufficient user expertise to be productive on Advanced.

Tozour Energy Services

THE POWER TO SAVE

106 Horizon Drive
King of Prussia, PA 19406
P: 610.962.1600 F: 610.962.0230

www.tozourenergysystems.com



Who is Tozour Energy Services?

Tozour Energy Services is the energy engineering consulting division of Tozour Energy Systems, Inc; a 200+ member full-service t and building automation provider serving Pennsylvania and New Jersey. Our dedicated group of energy professionals range from Certified Energy Managers (CEM) to Professional Engineers (PE) to Leadership in Energy and Environmental Design Accredited Professionals (LEED AP) in both new construction (NC) and existing buildings (EB).

Our mission remains simple: Help our clients create Master Green House Gas (GHG) and Energy Reduction Plans in an economically justified manner.

Our laser-focused mission begins with viewing your building energy requirements from a system approach rather than the traditional component examination. We investigate both sides of the meter; energy consumption and on-site power generation (traditional and renewable-"green") opportunities to increase savings potential.

In addition, to ensure that you avoid unfulfilled expectations and disappointments, we guarantee, validate and sustain measurable outcomes. These outcomes include specifics such as energy usage savings, utility expense reductions, LEED certification, annual energy and tax credits, rebates and incentives, comfort and reliability levels, and carbon dioxide (CO2) emission decreases.

Our unique approach will first exhaust all non-capital energy saving opportunities first before pursuing large capital investments like equipment replacement or upgrades. Combining fast payback opportunities with longer-term ones helps reduce or eliminate any initial capital investments. As your energy engineering consultant, we also understand the importance of providing you with objective and transparent data points enabling you to make a well-informed decision on any recommended Energy Conservation Measures (ECM). The following details what we can offer for you:

Retro-Commissioning

Our field and staff engineers and technicians analyze your key energy-consuming equipment and systems to uncover low-cost operating repairs and modifications that typically yield less than an 18-month payback. In addition, both an Energy User Index (EUI) and Energy Star rating establishes your facility's energy efficiency starting points. These benchmarks validate effectiveness of ECMs implemented, as well as document your commitment to going green.

Performance Testing

Our Technicians will perform a deep dive analysis on a specific piece of equipment that is critical to the operation of your facility. Using manufacturer's specifications, design data, measurement and testing we will quickly develop strategies to improve the efficiency, capacity, energy usage and overall operation of the equipment. Recommendations for capital and non-capital improvements will be provided along with project payback and environmental impact reduction calculations. Performance testing is available for centrifugal chillers, absorption chillers, boilers, air handling units, packaged rooftop units, cooling towers and pumps.

Energy Assessments

This program identifies capital-intensive ECMs, their associated paybacks and carbon emissions reduction. These ECMs consist of equipment upgrades and/or replacements, on-site generation and alternative technologies (solar, wind). Again, as you implement ECMs, the Energy Star and EUI ratings will enable a before and after comparison to ensure their effectiveness.

Our engineering team will use one of the industry-leading, energy-modeling programs, TRACE to simulate existing and future facility operating conditions and scenarios. These analyses will help determine what equipment selections provide the most measurable value (energy, CO2 reductions, costs, comfort, reliability, and the like) from a component and system perspective.

Energy Reduction Projects

Our project management experience and capabilities help us develop, install and sustain any ECMs you choose to pursue. And, we never lose sight that energy and the environment must also meet budget, cash flow and payback goals. Whether your project is non-capital or capital, self-funded or financed, Tozour Energy Services can help. Our team of professionals brings the combined experience of more than one billion dollars in new construction and $200+million dollars in energy-related projects for existing buildings.

Industries Served

Tozour Energy Services was recently selected to be a partner in the state of New Jersey's "Pay for Performance" program. We have developed strategies to save energy for an array of clients including K-12, higher education, health care, pharmaceutical, industrial and commercial real estate. In addition to those markets, a large power generation company chose Tozour Energy Services to be their nationwide provider of energy assessments and energy reduction projects.

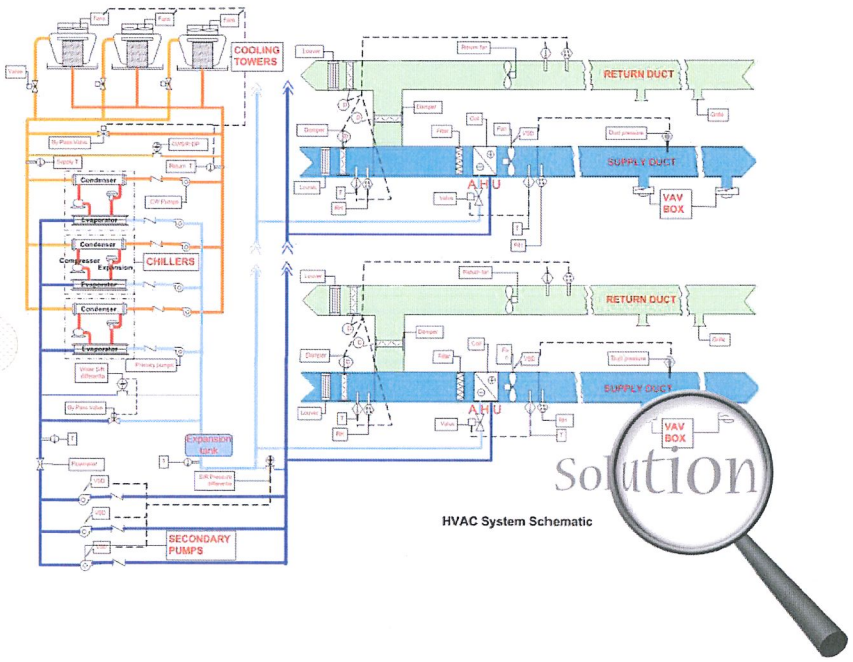
Tozour Energy Systems, Inc.

Tozour-Trane
HIGH PERFORMANCE BUILDINGS FOR LIFE

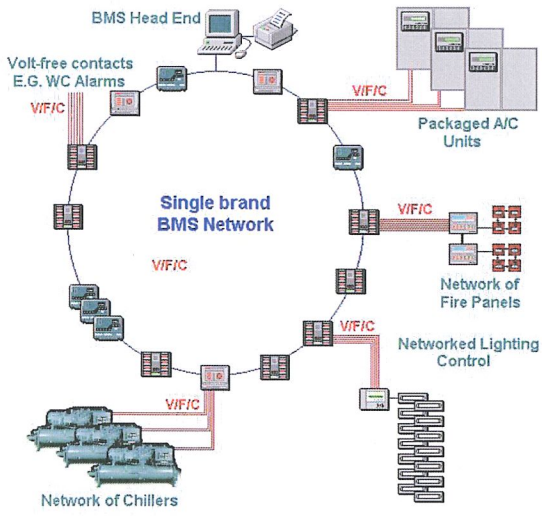
Tozour Energy Services
THE POWER TO SAVE

Tozour-Trane
HVAC PARTS & SUPPLIES

RETRO-COMMISSIONING



HVAC System Schematic



SCOPING STUDY PROPOSAL

741 FIRST AVENUE • KING OF PRUSSIA, PA 19406
P. 610.962.1600 • F. 610.962-0230
WWW.TOZOURENERGYSYSTEMS.COM

Tozour Energy Services
THE POWER TO SAVE

One Year Energy Usage Index (EUI) Sample Report

BUILDING	SIZE SQ FT	ELECTRIC			GAS		TOTAL ENERGY	EUI	
		Usage kWh	Demand kW	Cost $	Usage Therms	Cost $	Usage BTUs	Usage BTU / Sq Ft	Cost $ / Sq Ft
Building A	206,534	3,457,822	1,402	$484,095	171,454	$260,295	28,946,989,486	140,156	$3.60
Building B	215,190	2,986,751	1,380	$418,145	227,490	$345,785	32,942,781,163	153,087	$3.55
Total	421,724	6,444,573	2,782	$902,240	398,944	$606,080	61,889,770,649	146,754	$3.58

Energy Star Rating Assessment Sample Report

Target Energy Performance Results (estimated)			
Energy	**Design**	**Target**	**Top 10%**
Energy Performance Rating (1-100)	3	75	90
Energy Reduction (%)	N/A	22	38
Source Energy Use Intensity (kBtu/Sq. Ft./yr)	279.9	118.3	93.8
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	140.6	59.4	47.2
Total Annual Source Energy (kBtu)	57,789,980.0	24,422,300.6	19,374,618.1
Total Annual Site Energy (kBtu)	29,042,000.0	12,273,277.4	9,736,595.5
Total Annual Energy Cost ($)	$ 658,600	$ 278,327	$ 220,802
Pollution Emissions			
CO2-eq Emissions (metric tons/year)	2,728.4	1,153.1	914.7
CO2-eq Emissions Reduction (%)	-85%	22%	38%

Facility Information – 08057, United States

Facility Characteristics	
Space Type	**Gross Floor Area (Sq. Ft.)**
K-12 School	206,500
Total Gross Floor Area	206,500

Estimated Design Energy			
Energy Source	**Units**	**Estimated Total Annual Energy Use**	**Energy Rate ($/Unit)**
Electricity	kWh	3,500,000	$ 0.110/kWh
Natural Gas	therms	171,000	$ 1.600/therms

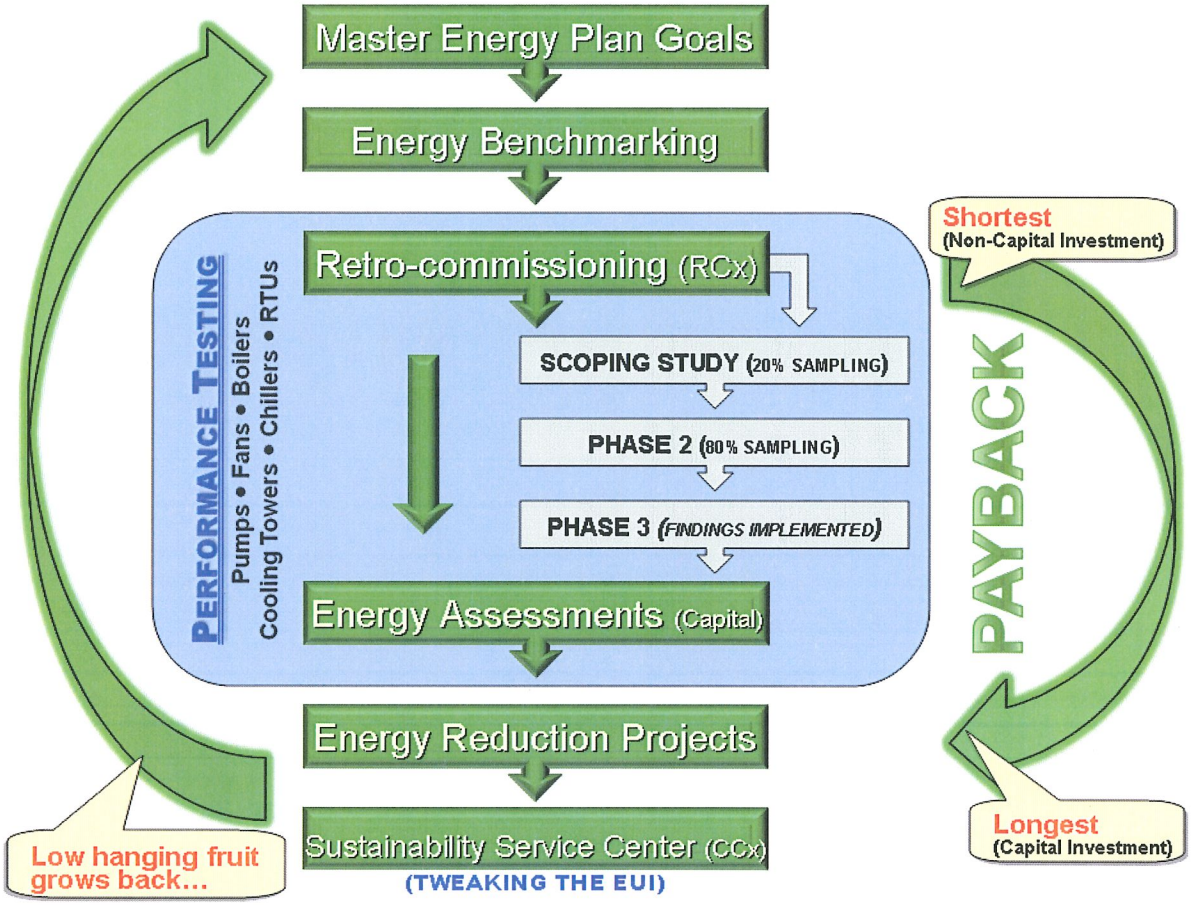
Source: Data adapted from DOE-EIA. See EPA Technical Description.

Report Section	Retro-Commissioning Measures	Cost to Implement Corrective Measures	Annual Savings	Simple Payback (Years)
3.2	Economizer Not Functioning Properly	$7,500	$42,854	0.18
3.3	Control Valve Leak-By	$10,000	$14,541	0.69
3.4	Inefficient AHU Temperature Controls	$4,500	$11,235	0.40
3.5	Missing Pipe Insulation	$17,500	$7,673	2.28
3.6	Inaccurate Instrumentation	$2,000	$4,246	0.47
3.7	AHU-9 Dehumidifier Operation During Periods of Humidification	$1,000	$1,600	0.62
3.8	Air Leaks	$0	$0	NA
3.9	Low Chilled Water Return Temperature	$0	See tonnage gain	NA
3.10	Missing Documentation (controls; BMS)	$0	$0	NA
TOTALS		$42,500	$82,153	0.52

Example of Non-Capital, short payback duration Energy Conservation Measures (ECM) typically found during a Retro-Commissioning Scoping Study. The Scoping study determines whether performing a Retro-Commissioning study on the rest of the facility is warranted.

Tozour Energy Services
THE POWER TO SAVE

The Master Energy Plan Process



Tozour Energy Services
THE POWER TO SAVE

Comparing Energy Audits to Retro-Commissioning

Energy Audit	Retro-Commissioning (RCX)
Definition • Analyzes energy-using equipment and building systems to define the implications of alternative energy-efficient measures • Identifies Energy Conservation Opportunities (ECOs) consisting of capital intensive equipment upgrades or replacements • Provides financial information to prioritize those projects • Uncover capital projects that typically yield a 10-15 year payback	**Definition** • Analyzes energy-using equipment to identify low-cost operational and maintenance improvements to optimize building systems • Uncovers low-cost, non-capital projects (1-3 year payback) **Retro-commissioning Three Phases:** 1. **Phase I Scoping Study:** Assess a sample of the building equipment to determine if conditions warrant Phase II RCx 2. **Phase II RCx:** Evaluate additional building systems and correct any deficiencies found during the Phase I Scoping Study 3. **Phase IIIRcX-** correction of all deficiencies found during Phase II through in-house staff, TES personnel or sub-contractors
Energy Audit Scope of Work • Review historical energy and operations data/utility bills • Field walk and inspect a sample of the building equipment: ▪ Boilers, chillers, air handler units, pumps ▪ Steam distribution systems ▪ Industrial gas systems and process equipment ▪ Compressed air and ventilation systems ▪ Backup generators • Define known, persistent operating problems with operators • Provide payback analysis for individual ECOs • Screen for utility rebates and incentives	**Phase I RCx Scoping Study Scope of Work** • Review energy consumption via utility bills • Calculate Energy Star or Energy User Index opportunities • Field Walk and inspect a sample of the building equipment: • Building Automation System • Air Handling Units • Chillers • Pumps • Boilers • Define known, persistent operating problems with operators Screen for utility rebates and incentives
Energy Audit Deliverable • A summary presentation detailing all identified ECOs.	**RCx Deliverables** **Phase I RCx Scoping Study** • Summary presentation showing any deficiencies or issues found **Phase II RCx** • Close out of issues found during Phase I RCx Scoping Study • Summary presentation detailing additional deficiencies found **Phase III RCx** • Close out of issues found during Phase II RCx
Energy Audit Next Steps • Present summary report • Prioritize ECO opportunities • Provide payback estimates for ECOs feasibility studies • Provide additional energy saving recommendations: o RCx Scoping Study o Procurement Advisory Services o Facility assessment screening	**Phase I RCx Scoping Study Next Steps** • Present summary report • Prioritize energy and operational opportunities • Provide payback estimates for non-capital recommendation • Provide additional energy saving recommendations o Phase II RCx o Energy Audit o Project feasibility study
Benefits • Identifies capital projects • Analyzes both supply- and demand- requirements • Identifies capital-intensive rebates • Develops cash flow pro forma for decision-making • Improves energy efficiency • Provides healthier indoor air quality • Improves occupant comfort	**Benefits** • Identifies non-capital projects, rebates, and simple paybacks • Reduces energy costs • Improves system performance • Reduces operational and maintenance requirements • Preserves capital investment • Improves energy efficiency • Provides healthier indoor air quality/Improves occupant comfort

Retro-Commissioning Scoping Study Proposal

Tozour Energy Services (TES) offers to conduct a Retro-Commissioning (RCx) Scoping study. This study will identify initial, non-capital (i.e.; process-driven) opportunities to reduce the site's energy consumption. Non-capital savings consists of energy conservation measures (ECMs) that provide paybacks of less than 18 months and don't require major equipment replacements. **NOTE:** The RCx Scoping Study determines if your facility qualifies for a total building retro-commissioning with favorable paybacks. The scoping study will be performed on 10% to 20% of the building's systems and equipment.

The study focuses on the identification of low-cost ways to:

- Improve energy efficiency; lower electric, gas, and steam/fuel costs
- Improve system performance
- Improve occupant comfort
- Reduce operational and maintenance requirements
- Create healthier indoor air quality

Our retro-commissioning team uses the best practices and lessons learned that we have developed from operating and maintaining (O & M) dozens of buildings. Before retro-commissioning your facilities, we review the O & M issues we encountered in similar systems, applications, and buildings we maintain. We use their resolutions to help focus our efforts in your facilities.

In addition, we use best practices and lessons learned from our Sustainability Services Center located in King of Prussia. We analyze hundreds of buildings to ensure they perform within the operating and efficiency parameters established. In summary, we continuously validate that your facilities sustain the gain of your investments and provide a performance report (see attached sample).

Scope of Work

TES will provide the following general methods of evaluation and testing for the RCx Scoping Study. We provide them for informational purposes to help explain the RCx process. TES tailors the study for each building to meet the sites needs. Our field and staff engineers and technicians analyze a sampling of your key energy-consuming equipment and systems to determine the following:

- How the HVAC and electrical systems originally were designed to operate
- How they operate today due to component and system changes made over the years
- How they should operate to obtain peak performance (such as energy, comfort, reliability, and IAQ) and the gap-analysis on what it will take to get them to that level (and sustain them)

Examples of retro-commissioning activities:

- Time of day scheduling updating
- Controls recalibration
- Economizer cycle adjustments
- Sequence of operations corrections
- Maintenance routines assessments
- Building Pressurization
- Ventilation Assessments

In addition, both an Energy User Index (EUI) and Energy Star rating establishes your facility's energy-efficiency starting points. These benchmarks validate effectiveness of ECMs implemented. . Our engineers also calculate the facility's existing Carbon Footprint. The sum represents the total amount of greenhouse gases released via electricity and fossil fuel consumption. These metrics document your corporate commitment to going green and could provide eligibility for various state and federal energy tax credits and/or rebates.

Three Step Process and Methodology

Step I :: HVAC Design Intent Review and Update

TES reviews the original *Design Intent* and determine if any changes in use, installation, etc. have modified it. The design intent defines:

- Hours of occupancy
- Desired space temperature, humidity and pressurization requirements
- IAQ (indoor air quality) requirements
- Ventilation rates for all spaces
- SOP (sequence of operations) and control strategies
- Code and safety requirements
- Reliability and redundancy requirements
- Energy consumption criteria

This phase requires the following to develop the Design Intent Document such as:

- Conduct a review of design drawings and schedules
- Review of control systems operations sequence and energy controls strategy
- Field survey area to ensure design documents is consistent with field conditions
- Review building operating logs and BMS trend information
- Interview the site HVAC group, utility group and building occupant/owner to confirm/update the HVAC design intent and define known, persistent operating problems

Step 2 :: Field Retro-Commissioning Activities

The Retro-Commissioning phase will include the required activities to systematically test, verify and evaluate the proper operation of selected equipment and systems. Our scope of work includes verification checks, functional testing of components and systems, identifying and cataloging of deficiencies. We review the sizing, selection, quality and accuracy of the installation as compared to the design drawings. In addition, we use data from the building automation system to determine operating efficiency of the components and systems and proper sequence of operation. If applicable, we will include heat load calculations and analysis.

TES will develop a Retro-Commissioning Plan before Retro-Commissioning the building. This plan outlines the verification checks and functional tests that will be conducted and details how we will implement the process. The plan also outlines the scope including the percentage of equipment and systems that will be tested. Typically, testing occurs on a representative sample between 10-20% as deemed necessary to qualify the building's potential for full retro-commissioning.

As we evaluate the sampling of selected equipment and systems, TES enters any discrepancies or deficiencies into an Issues Database. This document continuously gets updated and tracks items from discovery to resolution. It includes estimating the cost to repair/modify the deficiencies and any savings derived. TES Engineering will assist in resolving these issues during the Retro-Commissioning.

Step 3 :: RCx Scope Report Development and Presentation

At the conclusion of the assessment, we issue a formal PowerPoint report detailing the results and recommendations with supporting documentation including the issues database, test data, design information, calculations, and the like. The report also documents the quantified energy savings gained through the RCx process and any operational and maintenance related benefits.

Instrumentation/Methodology

- Water flow rates are measured with calibrated, non-intrusive, flow meters
- Water side pressures are measured with calibrated, test quality, bourdon tube pressure
- Pump/motor speed are measured with an NIST traceable tachometer.
- Motor amperage, voltage, power and power factor are measured with a true RMS power meter
- All test equipment NIST calibrated

Deliverable

TES will issue a summary report (two copies). It will contain field data sheets and computer-generated performance calculations and graphs. They will detail the results of the testing, all field observations, identified problems, and proposed recommendations. Each recommendation will include its costs, operational, and energy savings. Please see attached sample deliverable. Our engineering team will use one of the industry-leading, energy-modeling programs, to simulate existing and future facility operating conditions and scenarios.

Client Support Required

- Two years of electric, natural gas and fuel oil bills (with interval data if available)
- As-Built one-line diagrams of major energy systems
- Sequence of operations, O&M procedures and operating logs for major energy systems
- Any previously completed feasibility or energy studies
- HVAC and mechanical drawings and equipment schedules
- Previous balancing or vibration reports
- Access to or support on the BMS system

Revised: March 6, 2009

741 FIRST AVENUE • KING OF PRUSSIA, PA 19406 • (P) 610.962.1600 • (F) 610.962.0230 •

A Health Care Facility in Pennsylvania

Tozour Energy Services
THE POWER TO SAVE

741 FIRST AVENUE, KING OF PRUSSIA, PA 19406 | P: 610.962.1600 ▪ F: 610.962.0230 | WWW.TOZOURENERGYSERVICES.COM

Hospital's Goals

- Improve Energy Efficiency of the Building
- Examine Equipment Performance
- Help Create & Manage the Testing Plan
- Study The Building's Energy Characteristics
- Reduce Building Steam Usage
- Evaluate Retro-Commissioning Potential

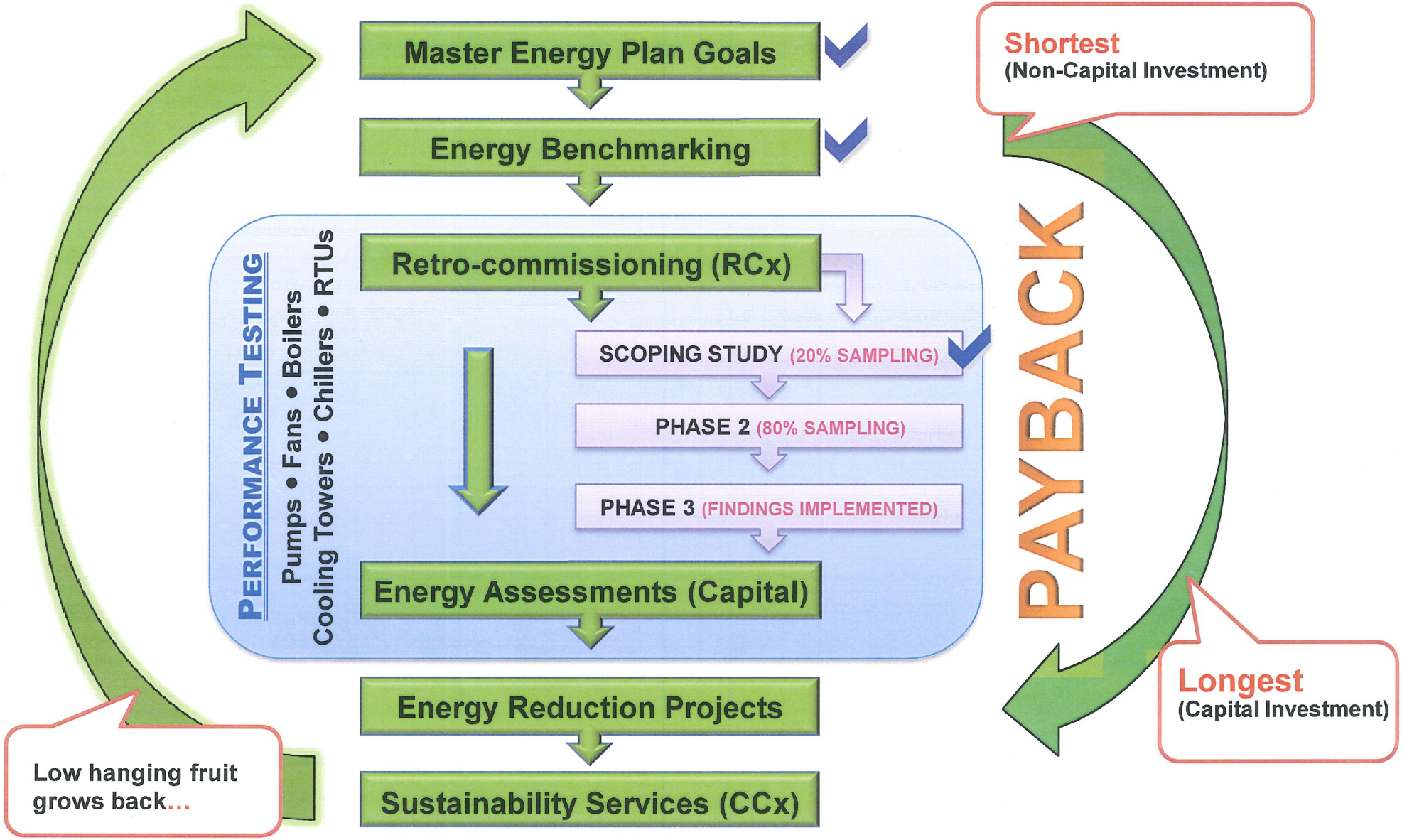
Hospital Overview

- Building System's Maintenance is Very Good
- Building is Clean & Comfortable
- Staff is Knowledgeable, Friendly, & Cooperative
- Thanks to the Staff for Help During Retro-Commissioning

Hospital Overview

- Built in The 1950s, Renovated in The 1980s
- 230,000 Sq Ft
- 15 Occupied Floors)
- Purchased Chilled Water & High Pressure Steam
- Hot Water Perimeter Heating System
- Hot Water Terminal Reheats
- Air Handlers With Steam Preheat & Chilled Water

The TES Approach



Tozour Energy Services
THE POWER TO SAVE

How We Do It

INTERNAL

- Tozour-Trane
- Trane
- Technicians
- Certified Energy Managers
- Professional Engineers
- Construction Managers
- Project Managers
- Controls Engineers
- HVAC Specialists
- Project Developers
- MBAs
- LEED APs

EXTERNAL

- Green Engineers
- LEED Consultants
- Lighting Companies
- On-site Power Experts
- Mechanical Contractors
- Load Curtailment Specialists
- Power Procurement

TECHNOLOGY &TOOLS

- Trace 700
- System Analyzer
- Training Center

TECHNICAL EXPERTISE

- Controls
- HVAC systems
- Cogeneration
- Turn key Projects
- Lighting
- Performance Contracting
- Building Operating Services
- CoGen/CHP



ENERGY ASSESSMENTS AND SERVICES

- Retro-commissioning
- Performance Testing
- Energy Reduction Projects
- Remote Sustainability Services
- Energy Credits
- Greenhouse Gases
- Financial Analysis
- Rebates
- Renewable energy

Retro-Commissioning Methodology

- Evaluate How Systems Should Function (Design)
- Evaluate How Systems are Functioning
- Perform a Gap Analysis Between the Two
- Evaluate Non-Capital Savings Potential
  - Time of day scheduling
  - Calibration issues
  - Economizer cycle
  - Simultaneous heating & cooling
- Conservative Savings Calculations
- Paybacks Typically < 18 Months

Focus Of The Scoping Study

- AHU-6, Serving Lab Area
- AHU-11, Serving Common Areas (All Floors)
- AHU-12, Serving Common Areas (All Floors)
- Reheat System
- Building Automation System

Systems tested chosen through conversation with Hospital Staff

Energy Usage Index (EUI)

Hospital, July 2008 through June 2009*

ELECTRIC					STEAM		CHILLED WATER		TOTAL ENERGY	EUI	
Usage kWh	Avg. Demand kW	Pk. Demand kW	Cost $	Avg. Load Factor	Usage MLbs	Cost $	Usage Ton Hours	Cost $	Usage BTUs	Usage BTU / Sq Ft	Cost $ / Sq Ft
5,397,728	714	785	$333,269	86%	28,301	$598,741	1,863,852	$500,488	57,161,652,090	244,919	$6.14

Calculations:

1 kWh of Electricity = 3,412 BTU

1 MLb of Steam = 1,150 BTU

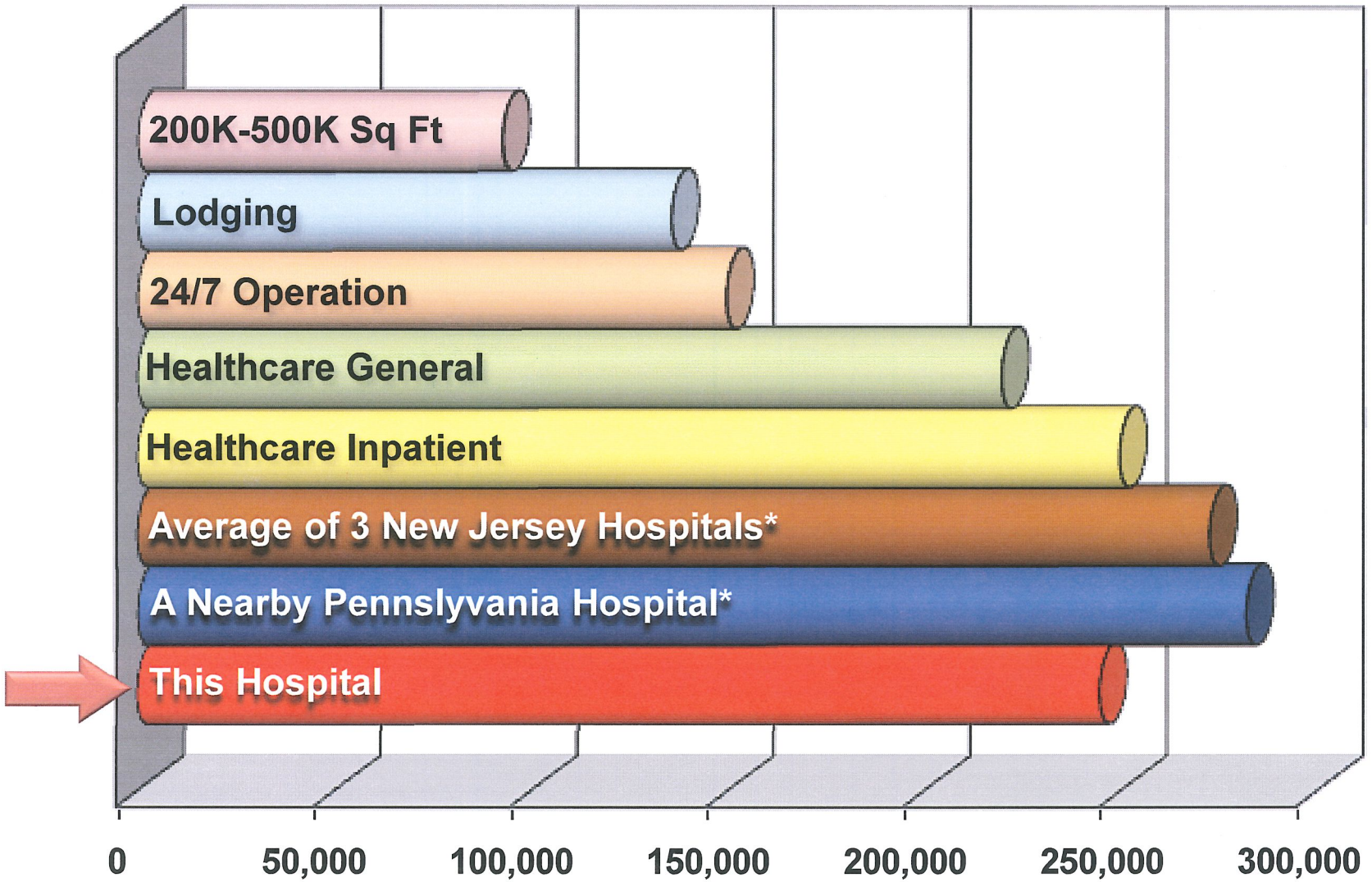
Building Square Footage = 235,000

Chiller Plant Efficiency = 0.76 kW/Ton

** EUI Calculated from data supplied by the Hospital*

Tozour Energy Services
THE POWER TO SAVE

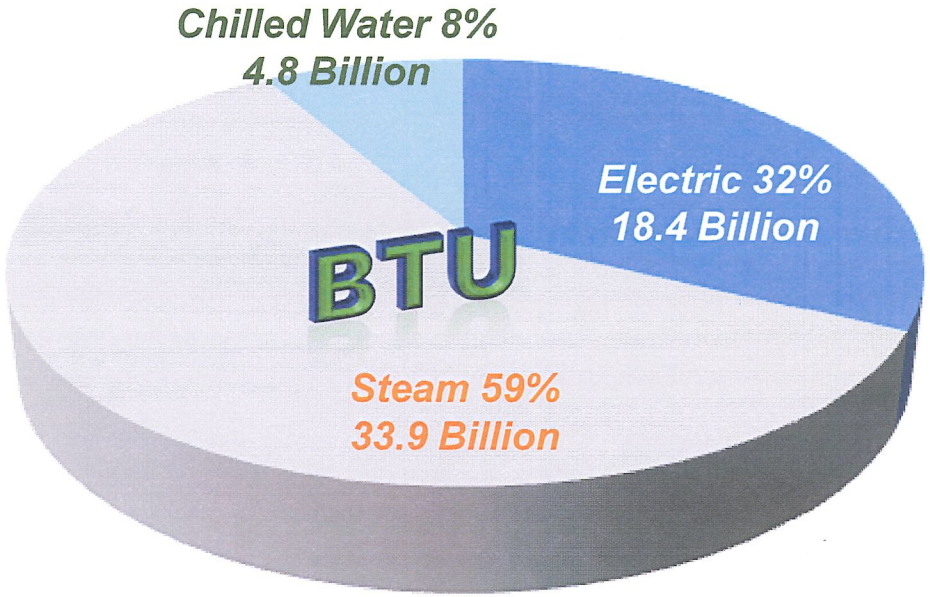
Energy Benchmarking (BTU/Sq Ft)

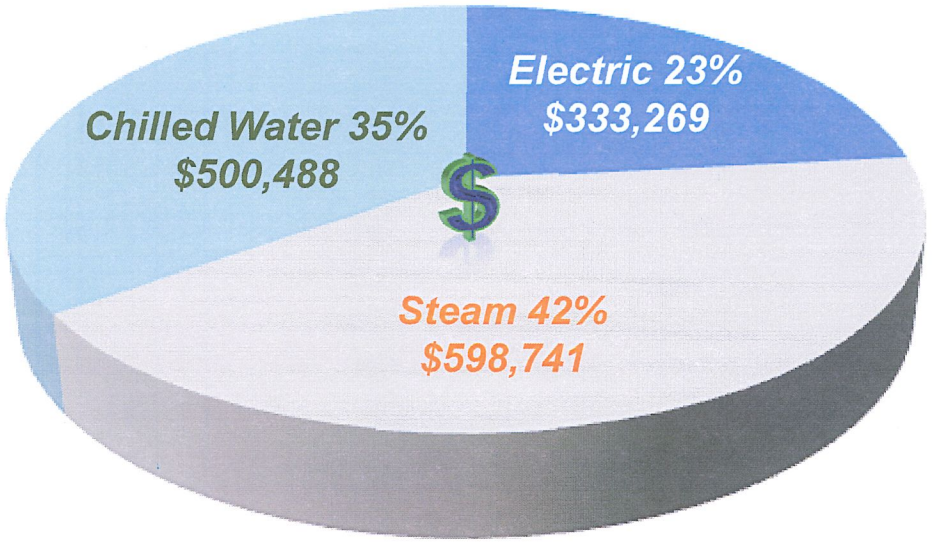


Source: Energy Information Administration, Commercial Buildings Energy Consumption Survey.
** New Jersey Hospitals do not purchase steam, neither NJ or PA hospitals purchase chilled water*

Tozour Energy Services
THE POWER TO SAVE

Energy Breakdown

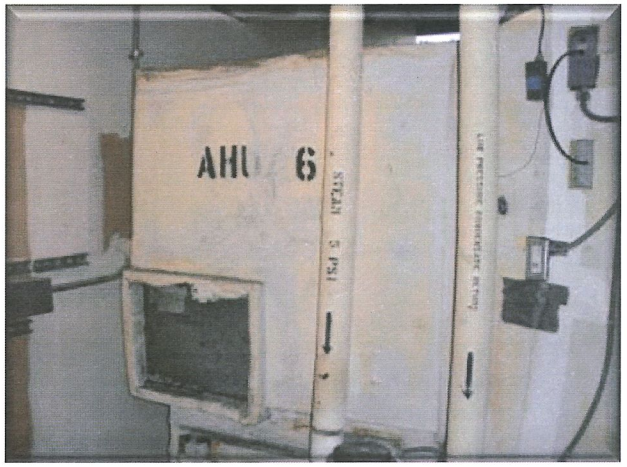




Tozour Energy Services
THE POWER TO SAVE

AHU-6 Overview

- Located on 4th Floor
- Serves Lab Area
- Retrofitted with VFD
- VFD Fixed at 55 Hz
- Maintains Temperature & Air Quality
- Potential Improvements
  - Economizer
  - Dampers
  - Duct Damage (Has been repaired)
  - VFD (Static control & seasonal setback)



AHU-6

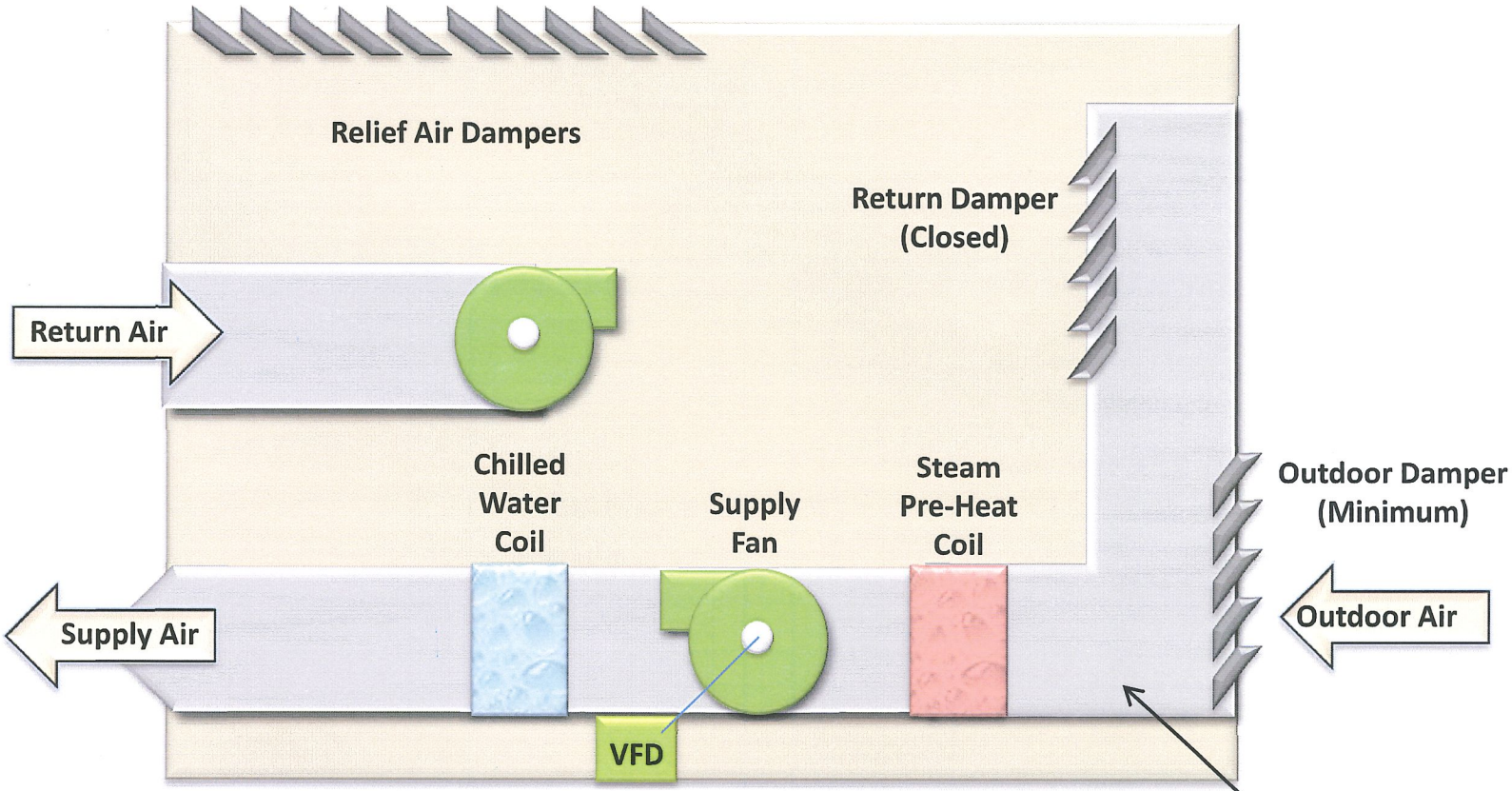


AHU-6 Return Fan

AHU-6 Initial Findings

- Controller is Not Commanding Unit in to Econ Mode
- Outdoor Damper at Minimum Position (Not in Econ Mode)
- Return Damper is Closed
- Duct Seal Torn Loose (Has Been Repaired Since)
- Ambient Conditions At Time Of Test
  - Outdoor Air Temperature = 70 Deg F
  - Outdoor Air Relative Humidity = 51%
  - Testing performed October 7, 2009

ECM 1 AHU-6 Economizer

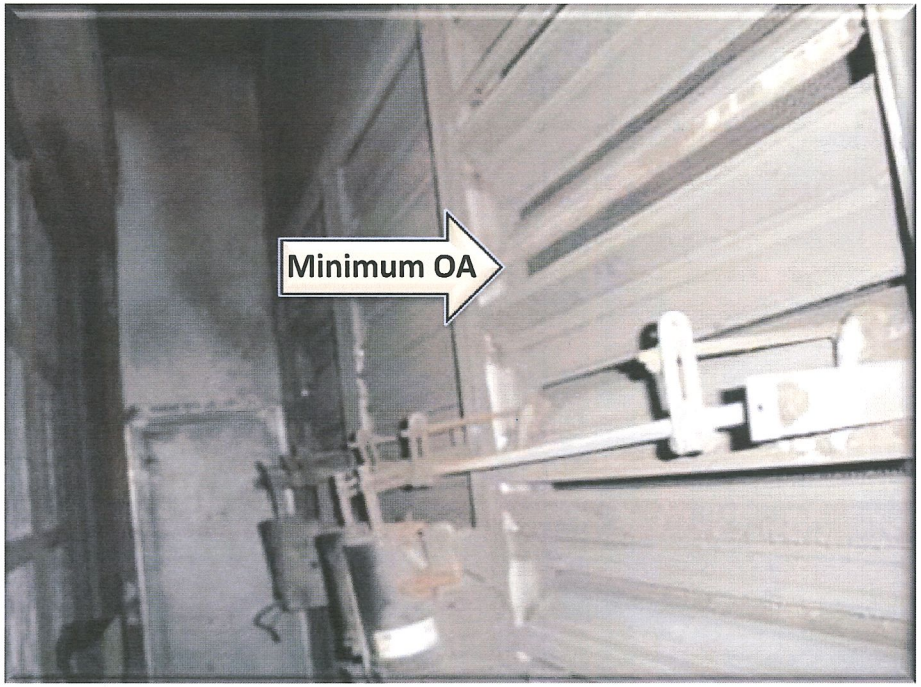


Block diagram of the AHU-6 Mechanical room that serves as the return air plenum,

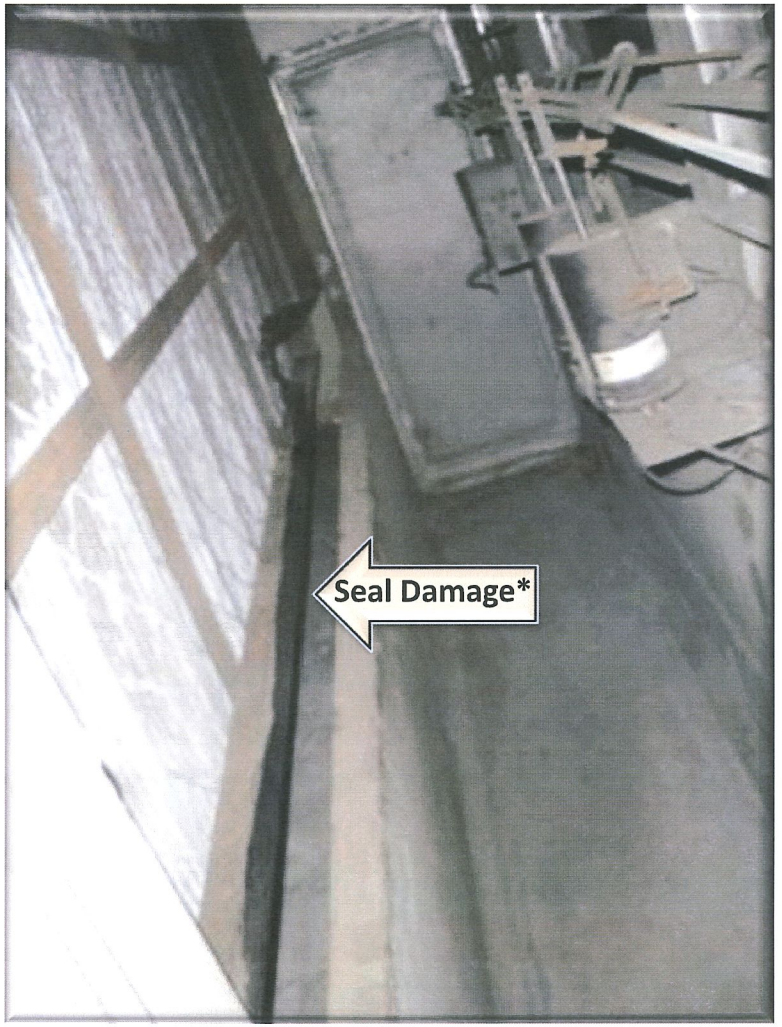
ECM = Energy Conservation Measure

Tozour Energy Services
THE POWER TO SAVE

ECM 1 AHU-6 Economizer



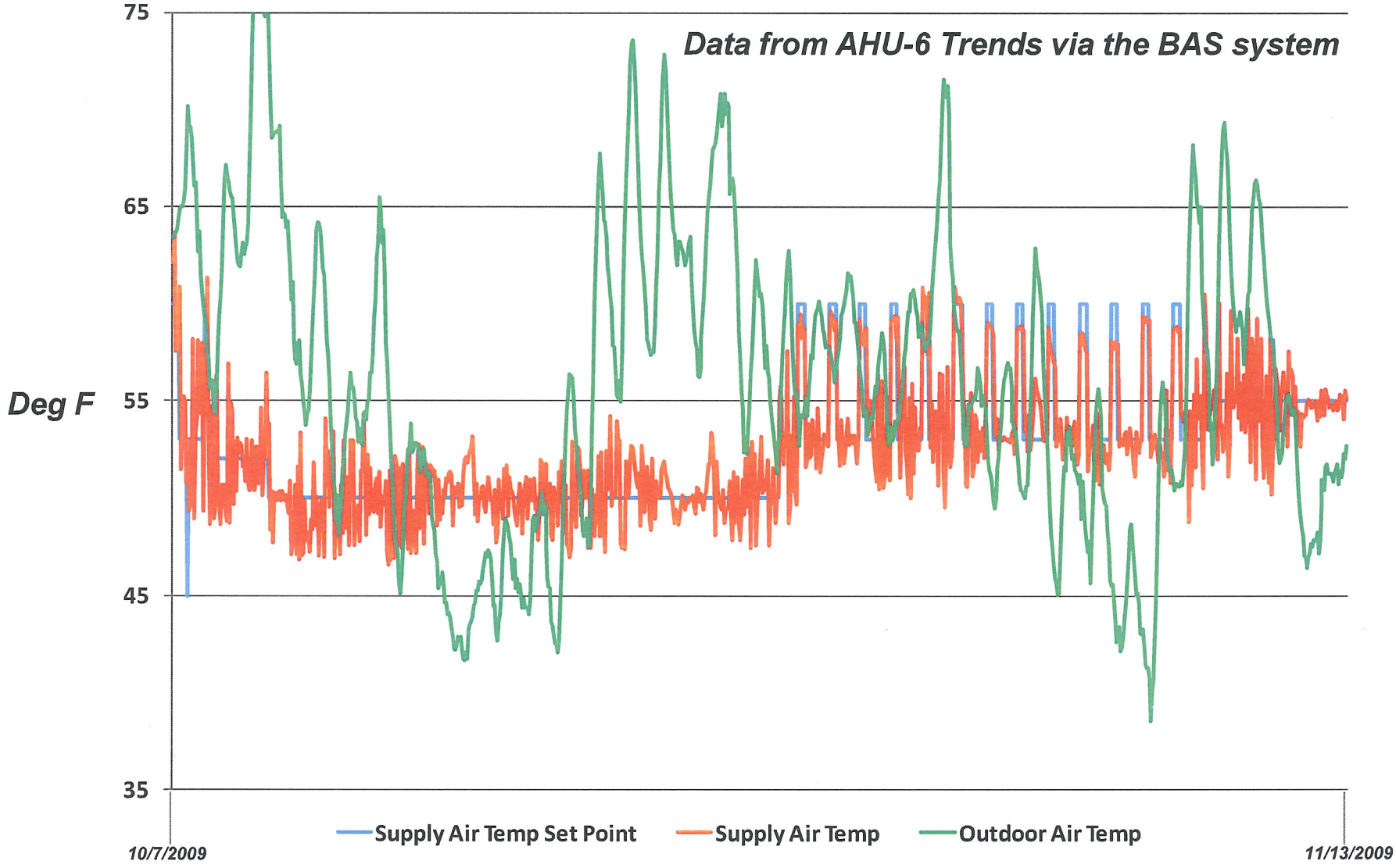
AHU-6 Outdoor Air Damper commanded to minimum despite outdoor air conditions favoring free cooling. Return Damper was 100% closed at the same time....



...which was the likely cause of damage to the duct seal in the mixed air plenum.

** Photograph shows opening in duct to the AHU-6 mechanical room which is the return air plenum for the unit*

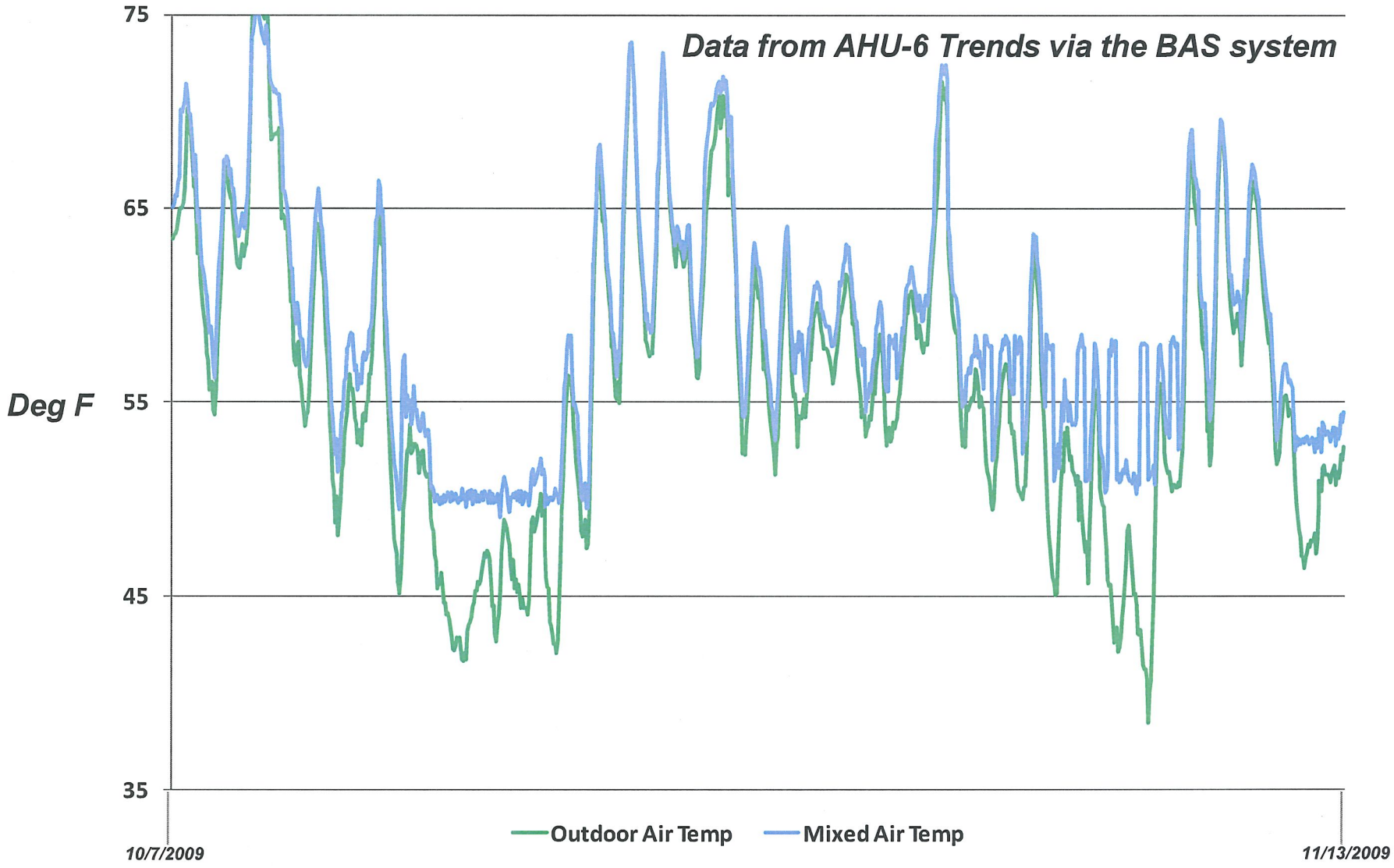
ECM 1 AHU-6 Economizer



Graph shows that AHU-6 should have been in free cooling mode for the majority of this time period

Tozour Energy Services
THE POWER TO SAVE

ECM 1 AHU-6 Economizer



Graph shows that despite AHU-6 Outdoor dampers being at minimum, mixed air temp tracks outdoor temp

Tozour Energy Services
THE POWER TO SAVE

ECM 1 AHU-6 Economizer

- Inoperative Economizer Normally an Energy Waster*
- AHU-6 Trend Data Indicates Unit is Starved for Air
- Mixed Air Temp is Low…
  - Outdoor dampers at minimum
  - Only return air path was the torn seal in duct
  - Outdoor air may be entering through relief dampers on the wall
- May Use Excessive Chilled Water in Summer
- May Use Excessive Steam Heating in Winter
- Recommend Repair to Econ Program & Return Damper

** Currently Unit is using excessive outdoor air*

ECM 2 AHU-6 VFD Setback

- Supply Fan VFD Runs Constantly At 55 Hertz
- Motor Savings Possible With Lower Fan Speed
- Lab Heat Load is a Concern
- Recommend “Shoulder Season” Gradual Setback
- Possible Winter Setback Potential Also
- Fan Motor Savings With Cubic Fan Laws

$$Power^{New} = Power^{Old} \times (CFM^{New}/CFM^{Old})^3$$

VFD = Variable Frequency Drive, 55Hertz (Hz) is 90% full fan speed

Tozour Energy Services
THE POWER TO SAVE

ECM 2 AHU-6 VFD Setback

TECHNICAL ASSUMPTIONS		RATIONALE
Annual amount of time AHU-6 fan may be able to be run slower (Hours)	2,880	Assuming 2.5 spring months (March to mid May) & 2.5 fall months (mid September to November) and 3 Winter months (December to February) approximately 240 days x 12 hours for per day (test starting
AHU-6 Fan speed reduction	10%	Reduction of fixed fan set point from 55 Hz to 50 Hz during spring, fall, & winter hours
AHU-6 supply fan motor (HP)	30	From mechanical schedule
AHU-6 supply fan motor energy (kW)	19	Motor HP (30) x constant (0.746) x conservative power factor assumption (85%)
AHU-6 supply fan motor energy usage at 60 Hz which is 100% speed (kWh)	54,786	Fan energy potential (19 kW) x annual set back run hours (2,880), NOTE: Total annual potential supply fan motor energy usage = 166,640 kWh
Electric cost per kWh ($)	$0.06174	Calculated average annual cost per kWh from utility data supplied by Hospital

COST & SAVINGS ANALYSIS		RATIONALE
AHU-6 actual supply fan motor energy at the fixed set point of 55 Hz which is 90% speed (kWh)	39,939	Annual energy at 60 Hz (22,828 kWh) x (new CFM / original CFM)^3 [22,828 kWh x (90% / 100%)^3]
Potential annual AHU-6 supply fan motor energy savings with an additional 10% reduction in fan speed 2,880 hours per year (kWh)	10,824	Annual energy at 55 Hz (39,939 kWh) minus [39,939 kWh x (new CFM / original CFM)^3]
Potential AHU-6 cost savings with 1,200 hours of 10% reduced speed ($)	$668	kWh savings (10,824) x electric rate ($0.062/kWh) NOTE: Additional savings would come from heating & cooling less airflow
Cost to implement ECM ($)	$500	Programming / scheduling change through the BAS system
Simple payback (Years)	0.7	ECM implementation cost ($500) / annual cost savings ($668)
CO_2 Saved (Tons)	8	kWh saved (10,824) x constant (0.00075)

Starting point to verify that the lower fan speed does not adversely effect the comfort or operation of the 3rd floor. Recommend a further decrease in fan speed for longer duration if this starting point works well.

Tozour Energy Services
THE POWER TO SAVE

AHU-6 Calibration

Parameter	BAS System	N.I.S.T. Calibrated Sensor	Units
Outdoor Air Temp	69.1	70.3	Deg F
Outdoor Air Humidity	76.2%	78.0%	% RH
Return Air Temp	73.1	73.0	Deg F
Return Air Humidity	45.0%	44.5%	% RH
Supply Air Temp	48.5	48.6	Deg F

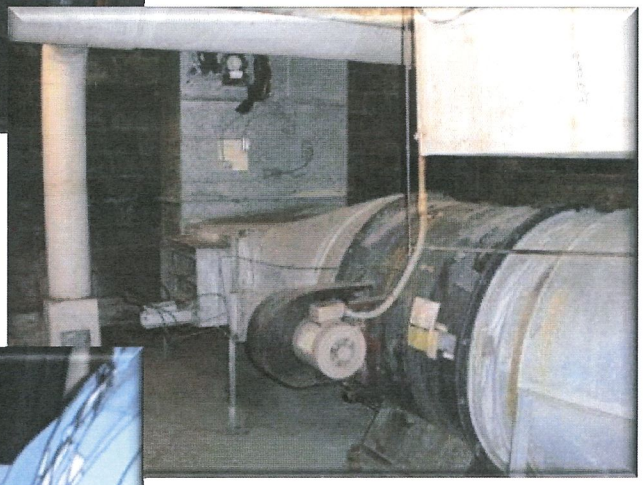
AHU-6 sensor calibration is very accurate

AHU-11 Overview

- Located in Penthouse
- Serves Corridors
- Energy Recovery Coil
- Air Flow Tested (N.E.E.B.)
- Potential Improvements
  - Economizer
  - Dampers
  - Starved fan
  - Outdoor air %
  - Energy Recovery



AHU-11



AHU-11 Return Fan

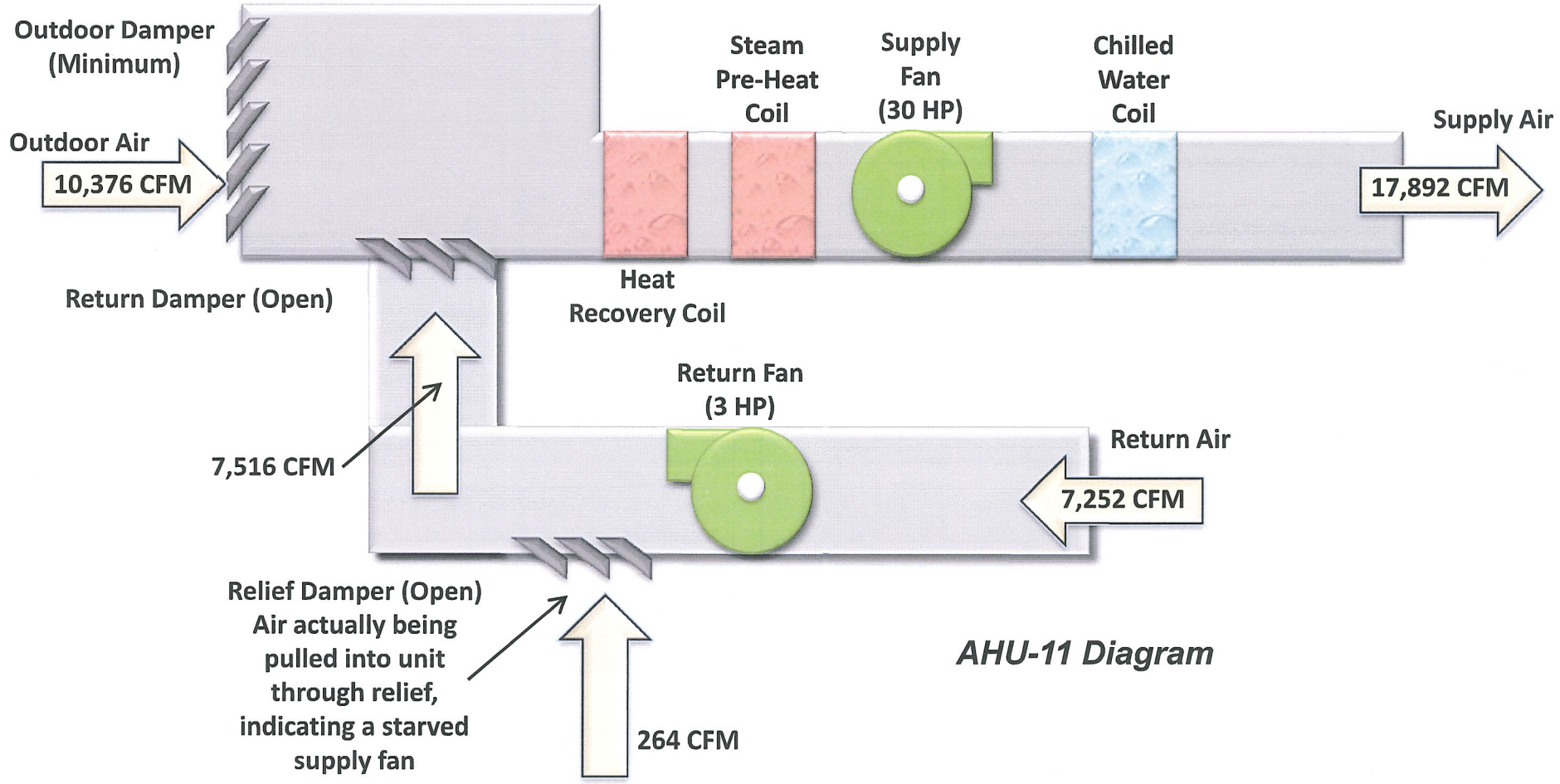


AHU-11 Flow Testing

ECM 3 AHU-11 Economizer

- Controller is Not Commanding Unit in To Econ Mode
- Outdoor & Return Dampers at Fixed Positions
- Conditions at Time Of Test
  - Outdoor air temperature = 39 Deg F
  - Outdoor air relative humidity = 82%
  - Return air temperature = 71 Deg F
  - Return air relative humidity = 31%
  - Testing performed October 16, 2009

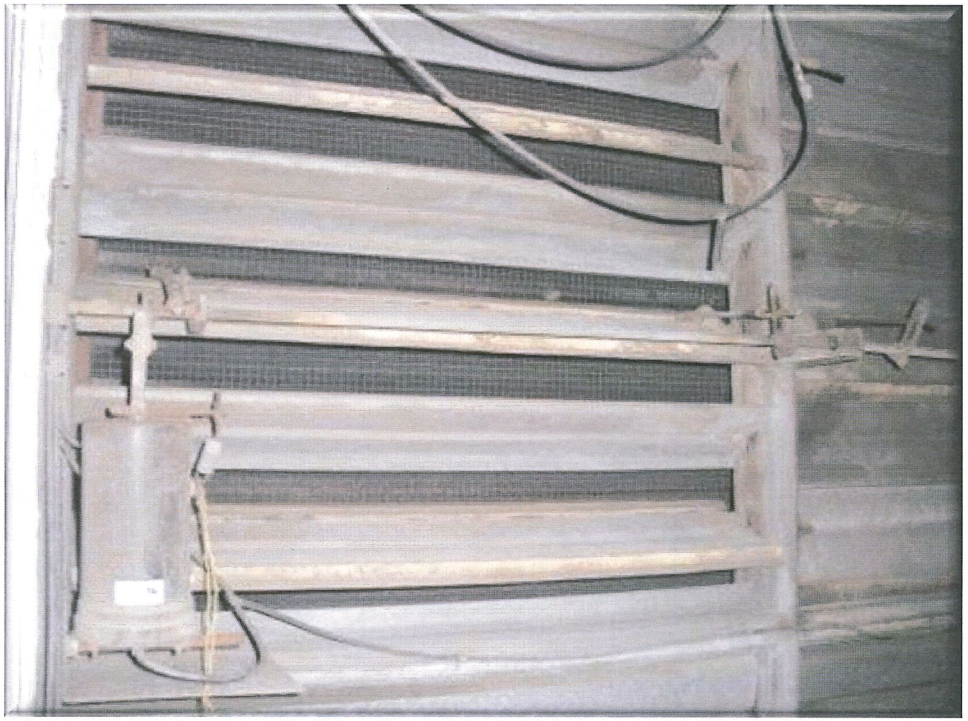
ECM 3 AHU-11 Economizer



AHU-11 Diagram

CFM Airflow readings are actual measurements taken with NEEB certified test equipment

ECM 3 AHU-11 Economizer

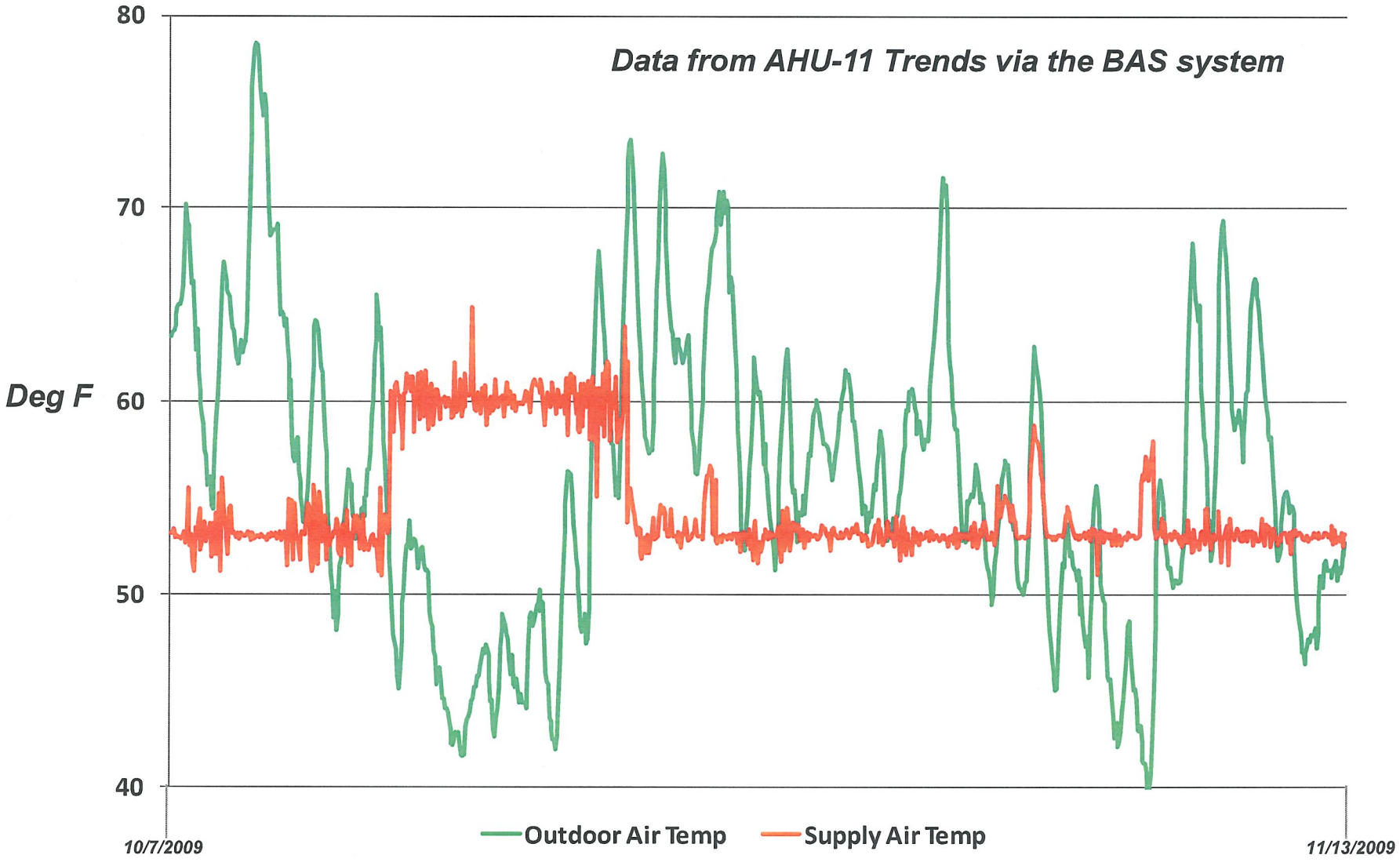


Outdoor air damper constant position



Return air damper constant position

ECM 3 AHU-11 Economizer



Graph shows AHU-11 maintains tight supply temp control, but there is opportunity for free cooling

Tozour Energy Services
THE POWER TO SAVE

ECM 3 AHU-11 Economizer

TECHNICAL ASSUMPTIONS		RATIONALE
Average AHU-11 supply temp set point during cooling mode (Deg F)	56	Trend data shows supply set point varies between 53 & 60 Deg F
Normal return temperature from building (Deg F)	72	Measured during testing and is typical for most buildings
Time per year when outdoor enthalpy favors economizer mode with no or little return air used (Hours)	1,650	Derived from historical outdoor air conditions for south eastern Pennsylvania Source: PECO Evaluator
Return air flow (CFM)	7,516	Measured at unit during "as is" running condition
AHU-11 Chilled water energy used to cool return air (BTU)	129,876	"Delta Temp across coil (72 deg return - minus average 56 deg supply) x constant (1.08) x return CFM (7,516)
Chilled water cost per Ton-Hour ($)	$0.08517	Calculated average cost per ton of cooling from utility data supplied by Hospital

COST & SAVINGS ANALYSIS		RATIONALE
Annual AHU-11 chilled water cooling savings (Ton Hours)	17,858	Chilled water BTU (129,876) / constant (12,000) x free cooling hours (1,650)
Annual cost savings ($)	$1,521	Ton Hr savings (17,858) x cost per chilled water ton hr ($0.085)
Left Blank	Left Blank	Left Blank
Cost to implement ECM ($)	$1,500	Programming change through the BAS system and damper linkage repair
Simple payback (Years)	1.0	ECM implementation cost ($1,500) / annual cost savings ($1,521)
CO_2 Saved (Tons)	10	Annual cooling energy saved (17,858 tons) x chiller plant efficiency (0.76%) x constant (0.00075)

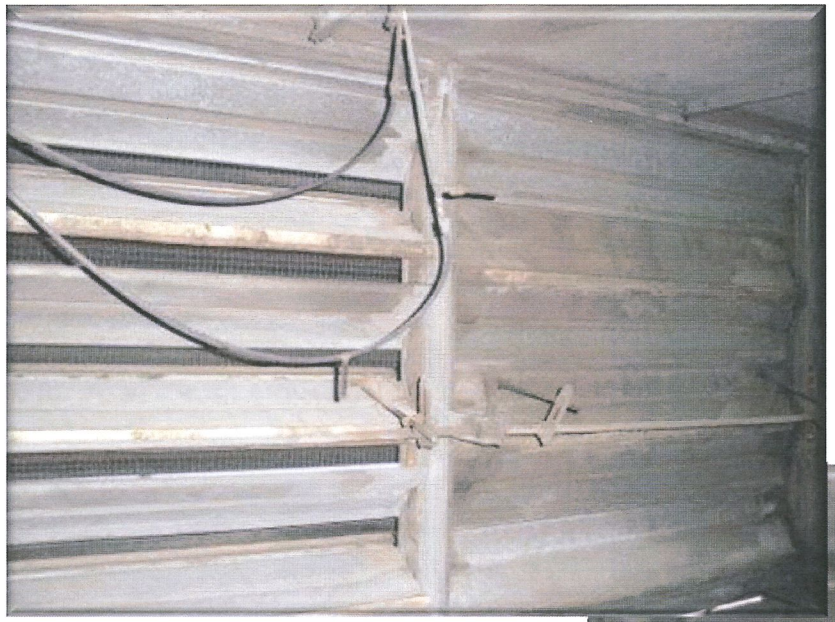
ECM 4 AHU-11 Increase Return Air

- Unit Design Calls For 65% Outdoor Air (16,080 CFM)
- Not Necessary for the Corridor Areas
- Actual Outdoor Air Flow Measured at 10,376 CFM
- Total Air Flow Measured at 17,892 CFM
- Total Design Air Flow is 24,740 CFM
- Dampers are Fixed Position (Not Under BAS Control)
- Supply Fan is Starved for Air
- Recommend Upsizing Return Fan Or Duct Work

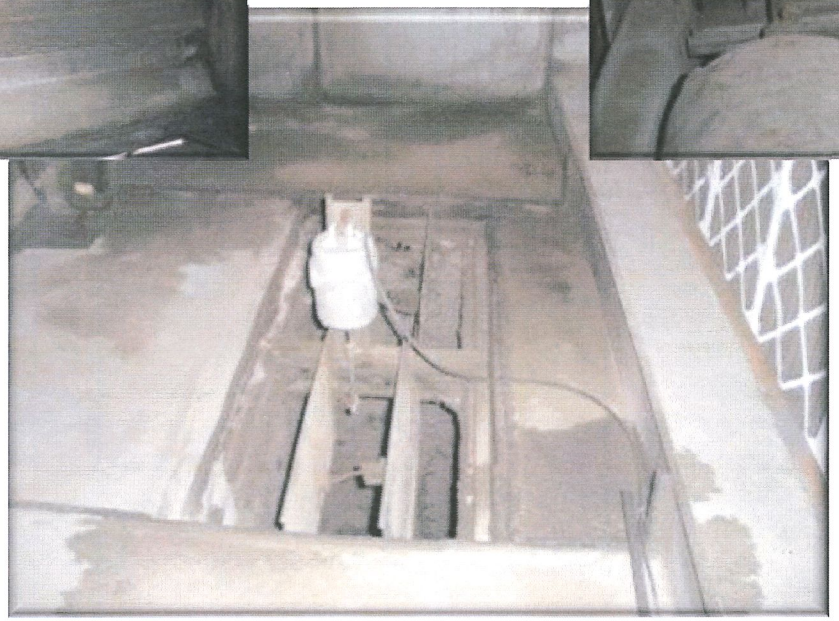
ECM 4 AHU-11 Increase Return Air

- Increase Size of Existing Return Air Duct Work
- Increase Return Air Flow By 4,000 CFM
- Reduce the Amount of Outdoor Air Used
- Let BAS System Take Control of Damper Operation
- Savings Through Heating & Cooling Less Outdoor Air

ECM 4 AHU-11 Increase Return Air



Outdoor air damper fixed minimum Delivers 10,376 CFM



Return air damper open 100%, delivers 7,516 CFM



Relief air damper – sucking in a paper towel (should be blowing out) Supply fan is drawing in 264 CFM through relief air damper

ECM 4 AHU-11 Increase Return Air

- Summer Savings From Reduced Outdoor Air (4,000 CFM)

  1.08 x 4,000 x (80° – 56°) = 103,680 BTU/Hr or 202.2 MMBTU

- Summer Cost to Cool Increased Return Air (4,000 CFM)

  1.08 x 4,000 x (72° – 56°) = 69,120 BTU/Hr or 134.8 MMBTU

- Summer Savings

  202.2 MMBTU – 134.8 MMBTU x((ton-hr)/0.012 MMBTU) x $0.08571/ton-hr = ***$478***

- Winter Savings From Reduced Outdoor Air (4,000 CFM)

  1.08 x 4,000 x (72° – 40°) = 138,240 BTU/Hr or 497.7 MMBTU

- Winter Cost to Cool Increased Return Air (4,000 CFM)

  1.08 x 4,000 x (72° – 626°) = 43,200 BTU/Hr or 155.5 MMBTU

- Winter Savings

497.7 MMBTU – 155.5 MMBTU x (Mlb/1,198,000 BTU) x (1,000,000 BTU/MMBTU) x $7.57/Mlb =

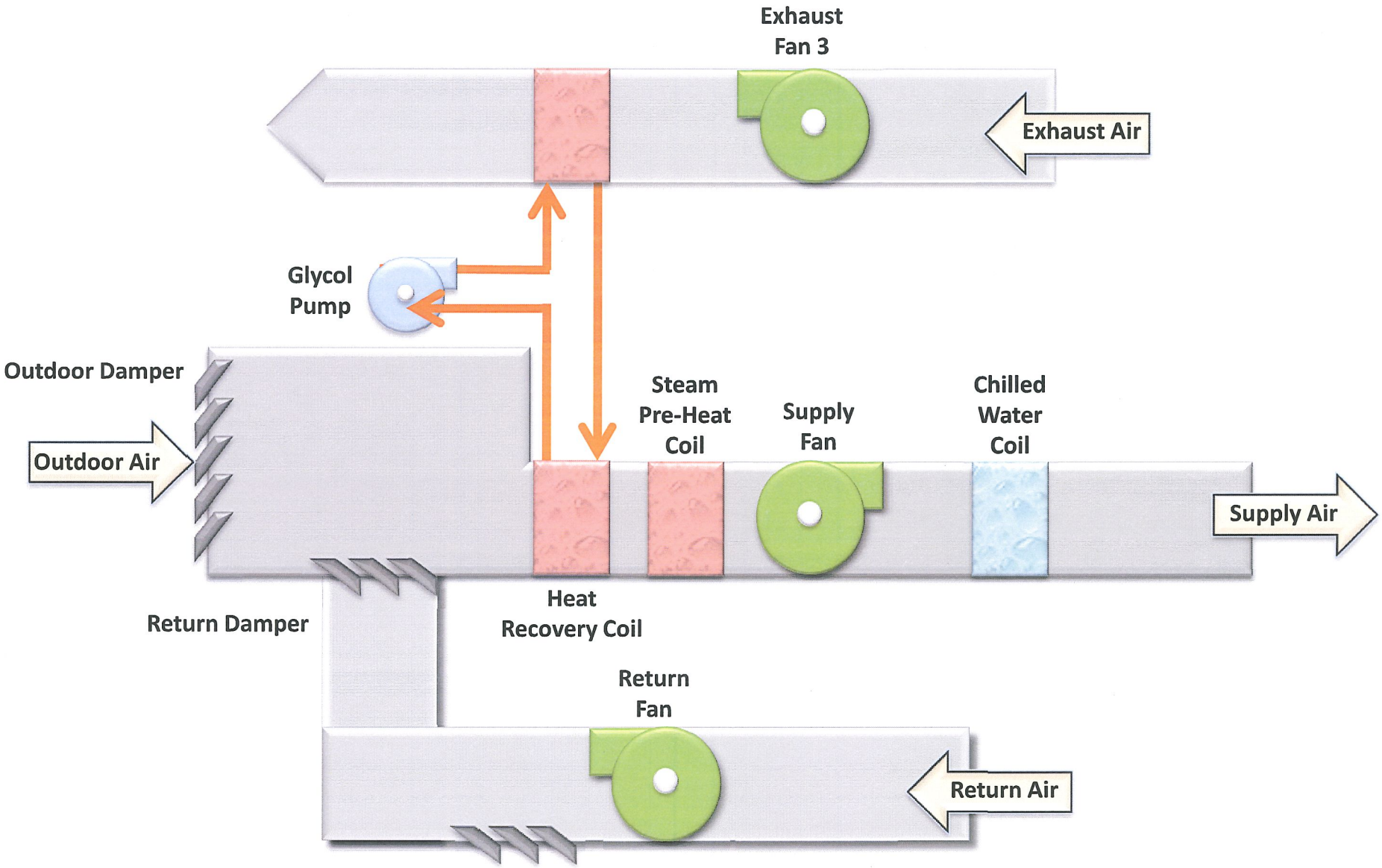
$2,162 *Total savings = $478 + $2,162 =* **$2,640**

Tozour Energy Services
THE POWER TO SAVE

ECM 5 AHU-11 Energy Recovery

- Heat Recovery System was Not Running During Test
- Exchanges Exhaust Heat to Incoming Air
- Coil Designed for Winter Capacity of 459 MBH
- Has the Potential to Save Steam Pre-Heating
- Slight Electric Usage Increase to Run Glycol Pumps

ECM 5 AHU-11 Energy Recovery



AHU-11 diagram with exhaust heat recovery

ECM 5 AHU-11 Energy Recovery

TECHNICAL ASSUMPTIONS		RATIONALE
Design AHU-11 heat recovery coil capacity (MBH)	459	From mechanical design
AHU-11 heat recovery coil design air entering temp (Deg F)	26	From mechanical design
AHU-11 heat recovery coil design air leaving temp (Deg F)	43	From mechanical design
AHU-11 actual measured airflow (CFM)	17,892	As measured during testing
AHU-11 heat recovery coil capacity with measured airflow (MBH)	330	Design Delta-T across coil (43 Deg F - 26 Deg F) x constant 1.08 x actual air flow (17,892 CFM)
AHU-11 average mixed air temp entering heat recovery coil during winter days with average outdoor temps <35 (Deg F)	46	Outdoor air data extrapolated from 2008 historical outdoor temps for Philadelphia, mixed air calculated by using measured outdoor air & return air flow and ratios, oa = 58%, ra = 42% in the unit's current as is condition
Amount of time AHU-11 average mixed air temp is 46 Deg F during winter months (Days)	43	Calculated from Philadelphia historical outdoor air temps for 2008, source: PECO E-Valuator
Steam cost per MLb	$7.570	Calculated incremental average cost per MLb of steam from last 5 bills supplied by Hospital

COST & SAVINGS ANALYSIS		RATIONALE
(Example) AHU-11 average temperature increase across heat recovery coil during winter months (Deg F)	8	Conservative estimate only, more data needed - actual exhaust system air temps and flows and actual glycol temperatures
Average heating energy used by heat recovery coil during winter months (BTU)	154,587	measured air flow (17,892 CFM) x estimated delta-T across coil (8 Deg F) x constant (1.08)
Total energy used in heating season by heat recovery coil (BTU)	159,533,660	Average coil energy (154,587 BTU) x winter hours (43 days x 24)
Potential steam savings for the steam preheat coil (MLbs)	133	Total winter recovery coil energy (159,533,660 BTU) / constant (1,198000)
Potential Steam cost savings	$1,008	Steam saved (133 MLbs) x cost per MLb of steam ($7.57)
Cost to implement ECM ($)	$200	Cost to run 5 HP glycol pump for 1,032 hours at current electric rate
Simple payback (Years)	0.2	ECM implementation cost ($200) / annual cost savings ($1,008)
CO_2 Saved (Tons)	4	Steam savings (139 MLbs) x constant (1,198,000) to convert to BTU / constant (100,000) to convert to therms of gas x plant & exchanger efficiency (50%) x constant (0.005)

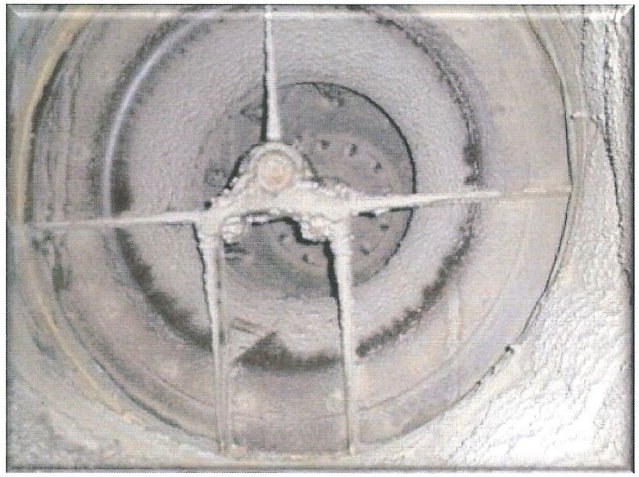
ECM calculated with AHU-11 running in the "as is" condition, more testing data needed to accurately determine true savings potential

Tozour Energy Services
THE POWER TO SAVE

AHU-11 Other Issues



Supply fan intake has irregular shape after apparent repairs



Return fan debris in the duct work, coating fan intake



Damage to return fan blades



Return fan housing with debris inside

May all contribute to lower than design air flow of this unit, supply duct is clean indicating good filter maintenance

Tozour Energy Services
THE POWER TO SAVE

AHU-11 Calibration

Parameter	BAS System	N.I.S.T. Calibrated Sensor	Units
Return Air Temp	71.7	72.5	Deg F
Return Air Humidity	55.0%	51.5%	% RH
Supply Air Temp	53.5	53.0	Deg F

Recommend calibrating return relative humidity sensor for accurate enthalpy calculation

AHU-12 Overview

- Located in Penthouse
- Serves Common Areas
- Energy Recovery Coil
- Potential Improvements
  - Economizer
  - Dampers
  - Energy Recovery
  - Fan Control

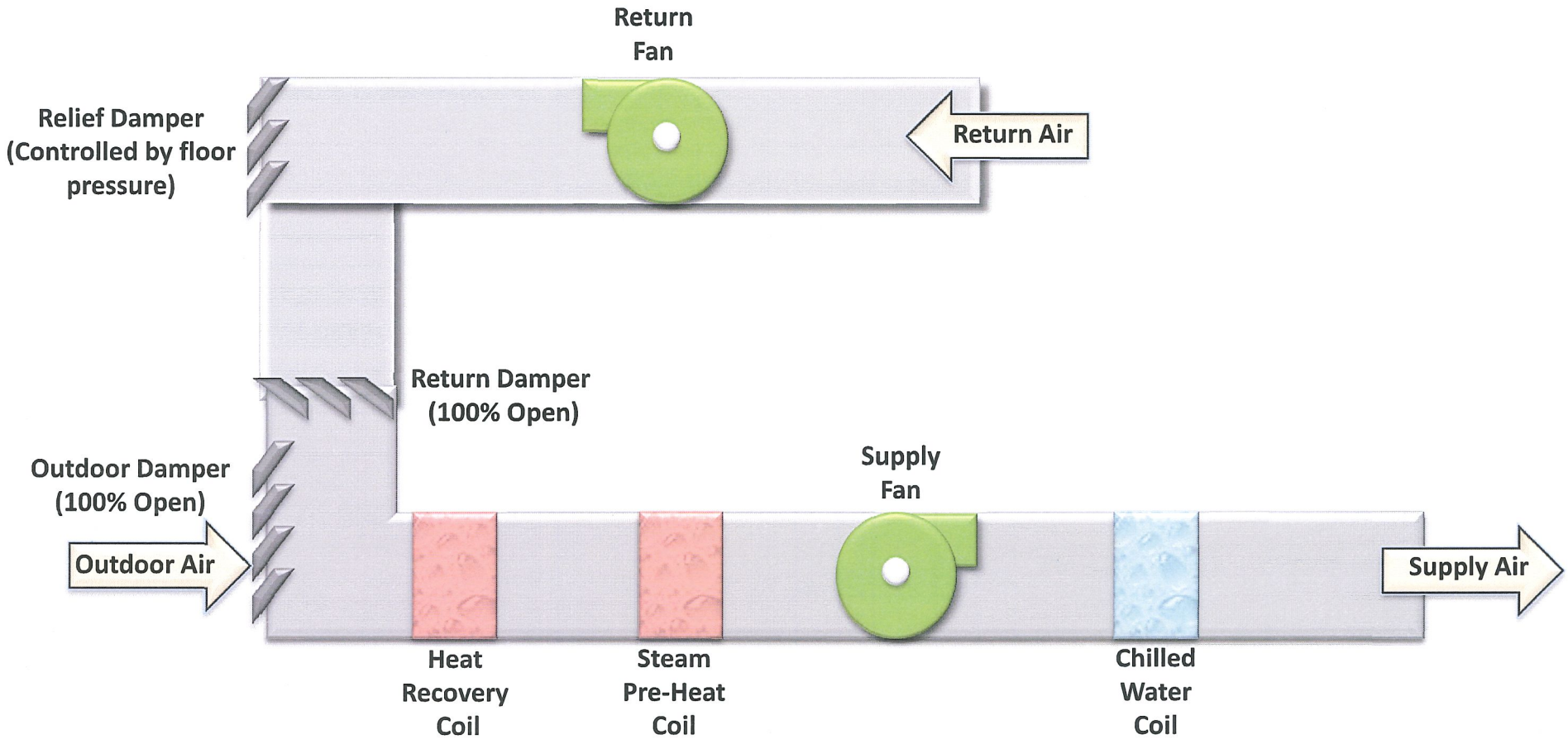


AHU-12

ECM 6 AHU-12 Economizer

- Controller is Not Commanding Unit in To Econ Mode
- Return Damper Stays Open When Forced in to Econ
- 100% Return Air Mixing With 100% Outdoor Air
- Conditions at Time of Test
  - Outdoor Air Temperature = 70 Deg F
  - Outdoor Air Relative Humidity = 51%
  - Testing performed October 7, 2009

ECM 6 AHU-12 Economizer

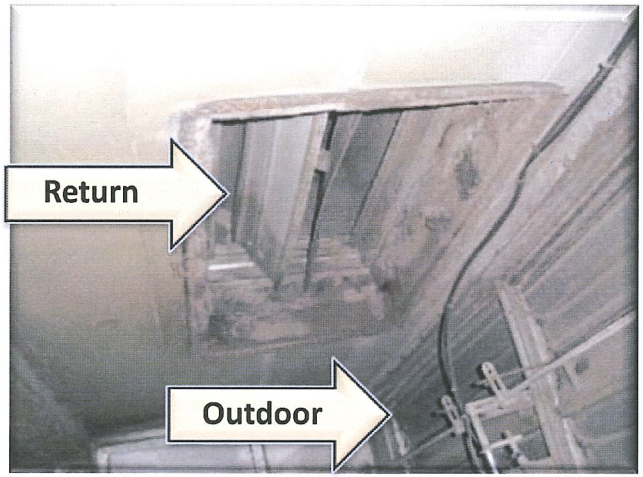


AHU-12 diagram, shown forced into Econ mode by the BAS system

CFM Airflow measurements were not taken on AHU-12 during this test

Tozour Energy Services
THE POWER TO SAVE

ECM 6 AHU-12 Economizer



AHU-12 NOT in Econ mode, outdoor damper at minimum, return damper open 100%

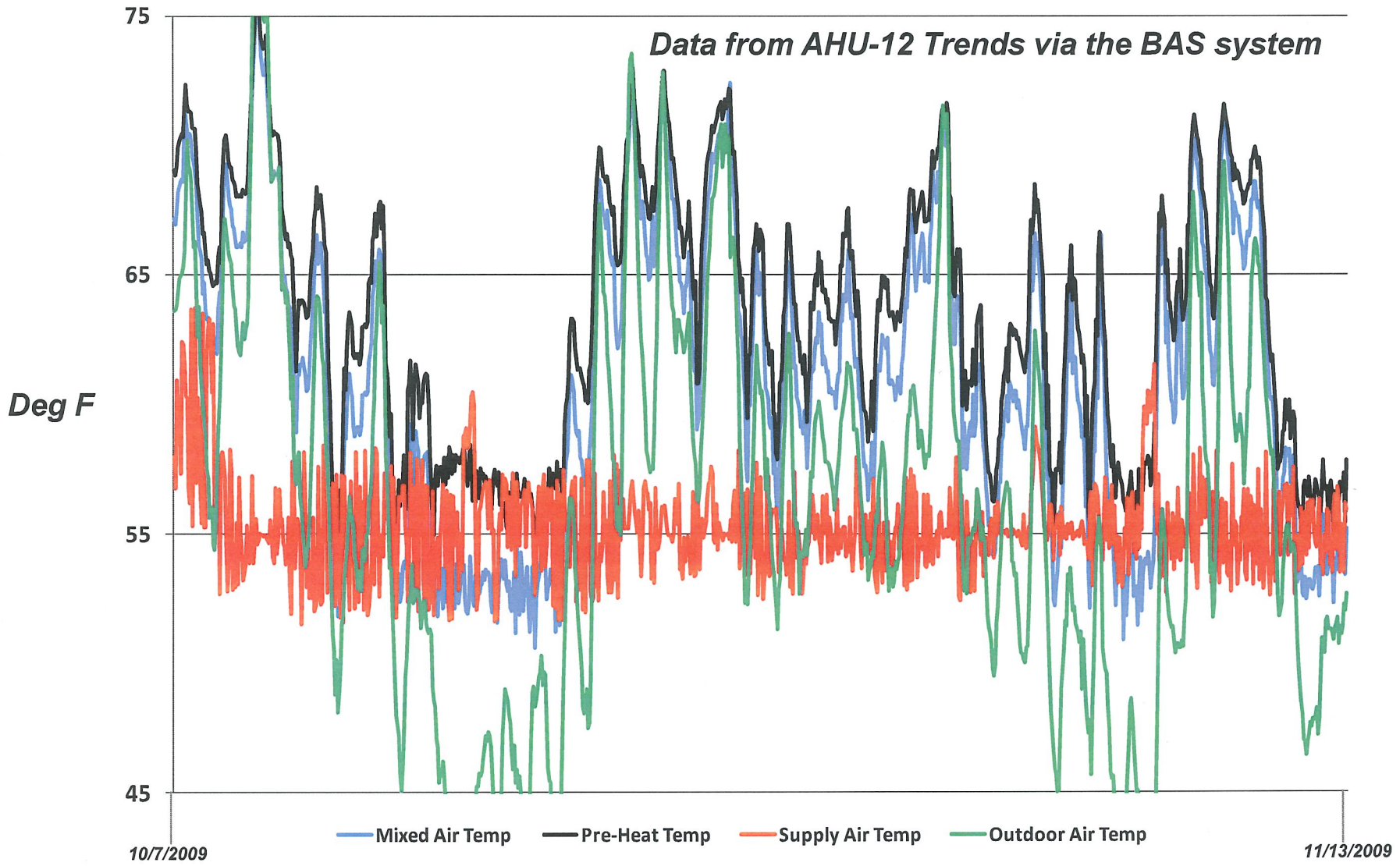


AHU-12 in Econ mode, outdoor damper open 100%....



...AHU-12 in Econ mode, return damper stays open 100%

ECM 6 AHU-12 Economizer



Graph shows AHU-12 maintains tight supply temp control, but there is opportunity for proper free cooling

Tozour Energy Services
THE POWER TO SAVE

ECM 6 AHU-12 Economizer

TECHNICAL ASSUMPTIONS		RATIONALE
AHU-12 design total air flow (CFM)	13,340	From mechanical design
AHU-12 design outdoor air flow (CFM)	6,680	From mechanical design (designed for 50% outdoor air)
Time per year when outdoor enthalpy favors economizer mode with no or little return air used (Hours)	1,650	Derived from historical outdoor air conditions for south eastern Pennsylvania Source: PECO Evaluator
AHU-12 design return air flow (CFM)	6,660	Total design air flow (13,340 CFM) - outdoor design airflow (6,680 CFM)
AHU-11 Chilled water energy used to cool return air (BTU)	71,928	Excess return air due to open return damper (6,660 CFM) x delta-t across coil (return temp 70 Deg F - supply temp 60 Deg F) x constant (1.08)
Chilled water cost per Ton-Hour ($)	$0.08517	Calculated incremental average cost per MLb of steam from last 5 bills supplied by Hospital

COST & SAVINGS ANALYSIS		RATIONALE
Annual AHU-12 chilled water cooling savings (Ton Hours)	9,890	Chilled water energy (71,928 BTU) / constant (12,000) x free cooling hours (1,650)
Annual cost savings ($)	$842	Ton Hr savings (9,890) x cost per chilled water ton hr ($0.085)
Left Blank	Left Blank	Left Blank
Cost to implement ECM ($)	$1,500	Programming change through the BAS system and possible damper linkage repair
Simple payback (Years)	1.8	ECM implementation cost ($1,500) / annual cost savings ($842)
CO_2 Saved (Tons)	6	Annual cooling energy saved (9,890 tons) x chiller plant efficiency (0.76%) x constant (0.00075)

ECM dependant on accuracy of design air flow parameters

AHU-12 Other Potential ECMs

- ECM 7 Reduced Outdoor Air Flow
  - Design outdoor flow is 50% (6,680 CFM)
  - Must determine what is needed
  - Air flows must be measured, re-balancing system probable
- ECM 8 Energy Recovery Loop
  - Same conditions as AHU-11
  - Smaller coil & less air flow will yield less savings
  - Further measurements must be taken for accurate savings
- ECM 9 Fan Speed Setback
  - Unit maintains a supply duct static
  - Further research on setback options needed

These ECM calculations would be similar to the previous VFD, outdoor air, & heat recovery ECMs for AHU 6 & 11

ECM 7 AHU-12 Outdoor Air %

TECHNICAL ASSUMPTIONS		RATIONALE
Current amount of AHU-12 outdoor air in normal (no economizer) mode (CFM)	6,680	From Mechanical prints
Design AHU-12 ratio of outdoor air flow to total unit air flow	50%	Design outdoor air (6,680 CFM) / design total air flow (13,340)
AHU-12 Assumption of total airflow needed in current run state (CFM)	4,002	Equates to 30% outdoor air; total air flow (13,340 CFM) x 30%, outdoor air flow will be reduced by 2,678 CFM
AHU-11 "Delta-T" across cooling & heating coils compared to return air temperature (Deg F)	Cooling = 7 Heating = 24	Assuming average summer outdoor temp = 80 Deg F and average winter outdoor temp = 45 Deg F [80 Deg F - summer ret. temp (73 Deg F) & winter ret temp (69 Deg F - 45 Deg F]
Steam cost per MLb	$7.570	Calculated incremental average cost per MLb of steam from last 5 bills supplied by Hospital
Chilled water cost per Ton-Hour ($)	$0.08517	Calculated average cost per ton of cooling from utility data supplied by Hospital

COST & SAVINGS ANALYSIS		RATIONALE
AHU-12 summer chilled water cooling savings (Ton Hours)	3,644	Assuming 3 months of 80 degree summer outdoor air; reduced outdoor CFM (2,678) x summer delta temp (7 Deg F) x constant (1.08) /constant (12,000) to convert BTU to Ton-Hrs
AHU-12 winter steam heating savings (MLbs)	125	Assuming 3 months of 45 degree winter outdoor air; reduced outdoor CFM (5,008) x winter delta temp (24 Deg F) x constant (1.08) /constant (1,198,000) to convert BTU to MLbs
AHU-12 potential savings with a reduction in outdoor air to 30% ($)	$1,258	Cooling savings (3,644 Ton-Hrs) x cost per chilled water ton ($0.085) + heating savings (125 MLbs) x cost per MLb of steam ($7.57)
Cost to implement ECM ($)	$1,500	Programming change through the BAS system and damper linkage repair
Simple payback (Years)	1.2	ECM implementation cost ($1,500) / annual cost savings ($1,258)
CO_2 Saved (Tons)	6	Steam savings (139 MLbs) x constant (1,198,000) to convert to BTU / constant (100,000) to convert to therms of gas x plant & exchanger efficiency (50%) x constant (0.005)

ECM dependant on accuracy of design air flow parameters

Tozour Energy Services
THE POWER TO SAVE

ECM 8 AHU-12 Energy Recovery

TECHNICAL ASSUMPTIONS		RATIONALE
Design AHU-12 heat recovery coil capacity (MBH)	181	From mechanical design
AHU-12 heat recovery coil design air entering temp (Deg F)	34	From mechanical design
AHU-12 heat recovery coil design air leaving temp (Deg F)	44	From mechanical design
AHU-12 Design Air Flow (CFM)	13,340	As measured during testing
AHU-12 heat recovery coil capacity with measured airflow (MBH)	144	Design Delta-T across coil (43 Deg F - 26 Deg F) x constant 1.08 x actual air flow (17,892 CFM)
AHU-12 average mixed air temp entering heat recovery coil during winter days with average outdoor temps <35 (Deg F)	46	Outdoor air data extrapolated from 2008 historical outdoor temps for Philadelphia, mixed air calculated by using measured outdoor air & return air flow and ratios, oa = 58%, ra = 42% in the unit's current as is condition
Amount of time AHU-12 average mixed air temp is 46 Deg F during winter months (Days)	43	Calculated from Philadelphia historical outdoor air temps for 2008, source: PECO E-Valuator
Steam cost per MLb	$7.570	Calculated incremental average cost per MLb of steam from last 5 bills supplied by Hospital

COST & SAVINGS ANALYSIS		RATIONALE
(Example) AHU-12 average temperature increase across heat recovery coil during winter months (Deg F)	8	Conservative estimate only, more data needed - actual exhaust system air temps and flows and actual glycol temperatures
Average heating energy used by heat recovery coil during winter months (BTU)	115,258	Design air flow (13,340 CFM) x estimated delta-T across coil (8 Deg F) x constant (1.08)
Total energy used in heating season by heat recovery coil (BTU)	118,945,843	Average coil energy (115,258 BTU) x winter hours (43 days x 24)
Potential steam savings for the steam preheat coil (MLbs)	99	Total winter recovery coil energy (118,945,843 BTU) / constant (1,198,000)
Potential Steam cost savings	$752	Steam saved (99 MLbs) x cost per MLb of steam ($7.57)
Cost to implement ECM ($)	$200	Cost to run 5 HP glycol pump for 1,032 hours at current electric rate
Simple payback (Years)	0.3	ECM implementation cost ($200) / annual cost savings ($752)
CO_2 Saved (Tons)	3	Steam savings (103 MLbs) x constant (1,198,000) to convert to BTU / constant (100,000) to convert to therms of gas x plant & exchanger efficiency (50%) x constant (0.005)

ECM dependant on accuracy of design air flow parameters

Tozour Energy Services
THE POWER TO SAVE

ECM 9 AHU-12 Reduced Air Flow

TECHNICAL ASSUMPTIONS		RATIONALE
Annual amount of time AHU-12 fan may be able to be reduce air flow	2,880	Assuming 2.5 spring months (march to mid may) & 2.5 fall months (mid September to November) and 3 winter months (December to February) approximately 240 days x 12 hours for per day (test starting
AHU-12 air flow reduction	10%	Reduction of fixed fan set point from 55 Hz to 50 Hz during spring & fall off hours
AHU-12 supply fan motor (HP)	20	From mechanical schedule
AHU-12 supply fan motor energy (kW)	13	Motor HP (30) x constant (0.746) x conservative power factor assumption (85%)
AHU-6 supply fan motor energy usage at full air flow (kWh)	36,524	Fan energy potential (13 kW) x annual set back run hours (2,880)
Electric cost per kWh ($)	$0.06174	Calculated average annual cost per kWh from utility data supplied by Hospital

COST & SAVINGS ANALYSIS		RATIONALE
Left Blank	Left Blank	Left Blank
Potential annual AHU-12 supply fan motor energy savings with an additional 10% reduction in fan speed 2,880 hours per year (kWh)	9,898	Annual energy at 55 Hz (36524 kWh) minus [36,524 kWh x (new CFM / original CFM)^3]
Potential AHU-12 cost savings with 2,880 hours of 10% reduced air flow ($)	$611	kWh savings (4,510) x electric rate ($0.062/kWh) NOTE: Additional savings would come from heating & cooling less airflow, actual AHU-6 airflow is unknown
Cost to implement ECM ($)	$500	Programming / scheduling change through the BAS system
Simple payback (Years)	0.8	ECM implementation cost ($500) / annual cost savings ($611
CO_2 Saved (Tons)	7	kWh saved (9,898) x constant (0.00075)

ECM dependant on accuracy of design air flow parameters

AHU-12 Calibration

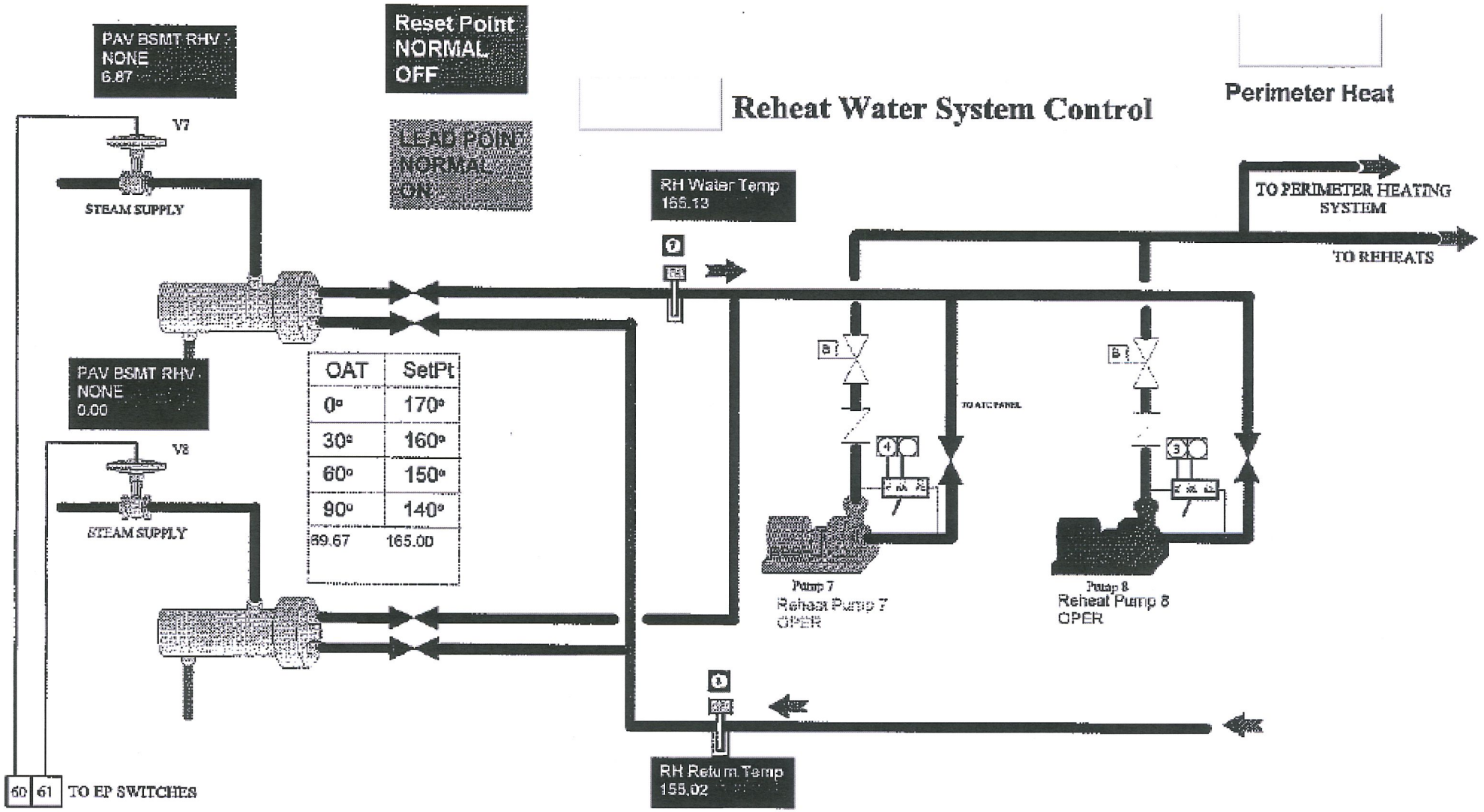
Parameter	BAS System	N.I.S.T. Calibrated Sensor	Units
Return Air Temp	72.1	72.3	Deg F
Return Air Humidity	40.8%	58.3%	% RH
Supply Air Temp	60.6	60.7	Deg F

Recommend calibrating return relative humidity sensor for accurate enthalpy calculation

Reheat System Overview

- Located in Basement
- 175 Psi Steam Source
- Steam Reduced to 10 Psi For Heat Exchangers
- Cross Connect to Perimeter Heating System
- Hot Water Reset from Outdoor Air Temp
- Controlled by BAS System
- Pump 8 Under Repair at Time of Test
- Test Conditions; Outdoor Air Temperature = 47 Deg F

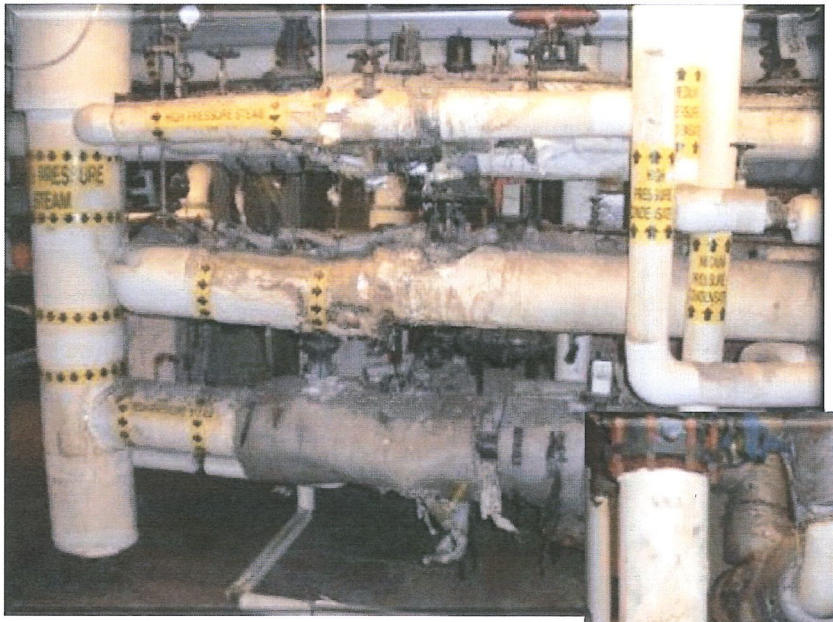
Reheat System Overview



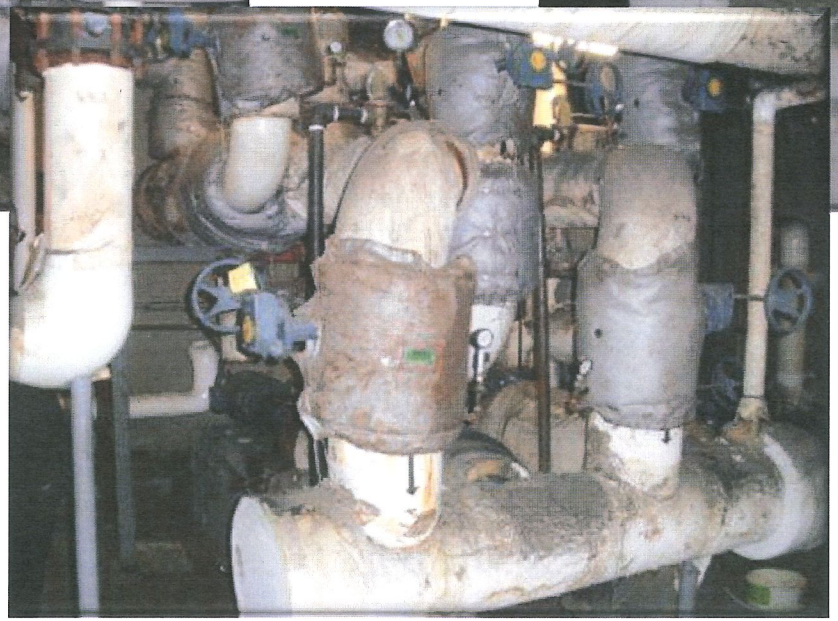
Screen shot of re-heat system from the BAS system

Tozour Energy Services
THE POWER TO SAVE

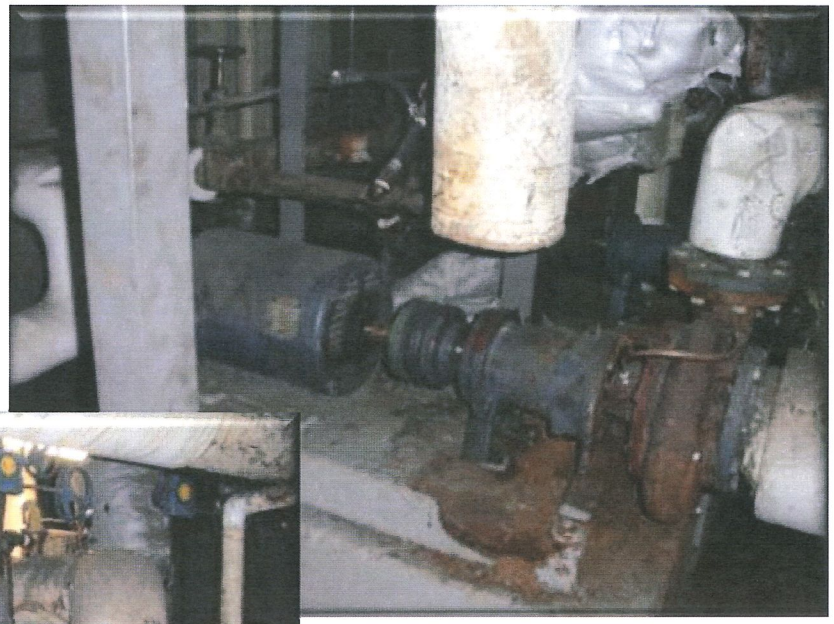
Reheat System Overview



Incoming high pressure steam

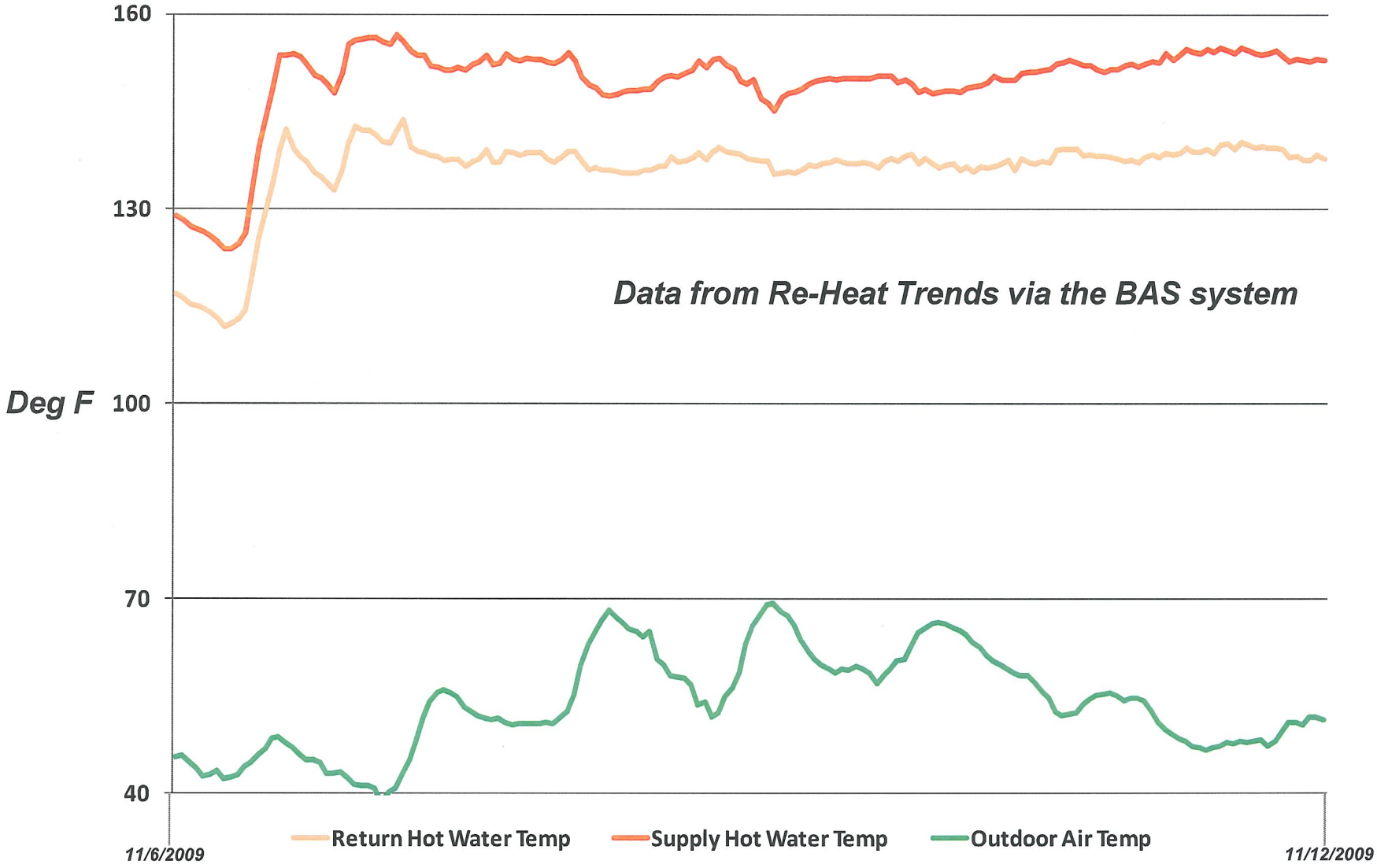


Supply & return hot water to heat exchangers



Re-Heat hot water pumps

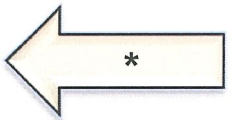
Reheat System Trend Data



Tozour Energy Services
THE POWER TO SAVE

Reheat System Flow Data

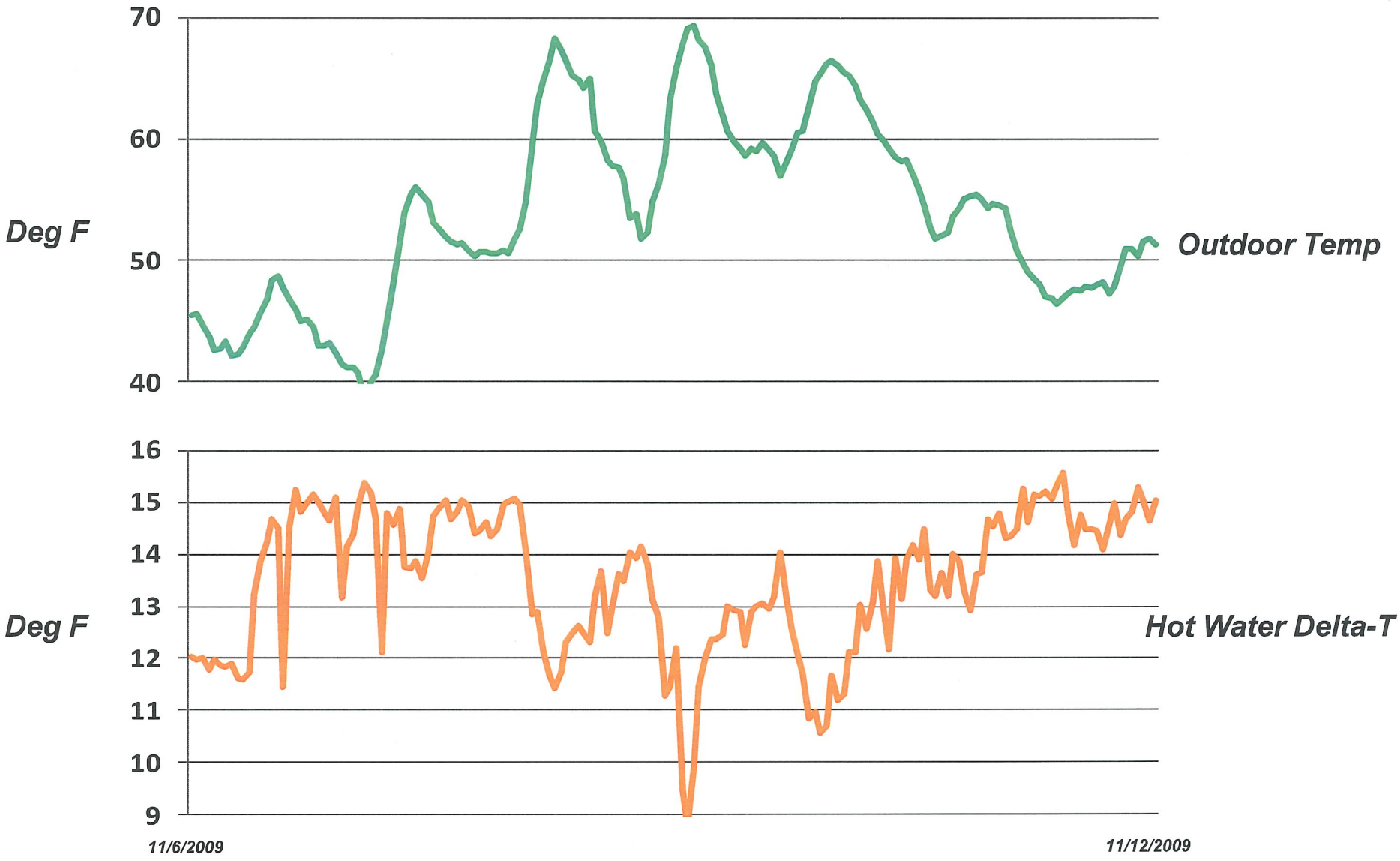
Date	Time	Outdoor Temp	Hot Water GPM
10/19/2009	9:45	42.6	236
10/19/2009	10:30	44.6	251
10/19/2009	11:00	46.6	243
10/19/2009	13:45	53.1	338



Measurements taken with an Ultra-Sonic Flow meter

* *Significant increase in flow , reason is unknown*

Reheat System Trend Data



Tozour Energy Services
THE POWER TO SAVE

Reheat System Further Investigation

- Heat Exchanger Design Flow = 580 GPM
- Original Pump Design Flow = 580 GPM
- Current Pump Design Flow = 800 GPM
- System Comprised of 2 Way & 3 Way Valves

ECM 10 Reheat Schedule

- Hot Water Set Point Controlled by BAS System
- Need to Qualify The Current System Set Points
- Set Points Higher Than Other Building's Reset Schedules*

Outdoor Temp	Hot Water Set Point
0	170
30	160
60	150
90	140

Current reset schedule

Outdoor Temp	Hot Water Set Point
0	170
30	158
60	148
90	130

Proposed reset schedule (starting point)

* *Typical Buildings, even hospitals may reduce hot water reheat set point to 120-130 Deg F with outdoor temp > 60*

ECM 10 Reheat Schedule

TECHNICAL ASSUMPTIONS		RATIONALE
Reheat system average flow rate (GPM)	240	As measured during testing with outdoor air temperature = 47 Deg F
Average Delta-T between supply and return hot water temp (Deg F)	13.5	Derived from BAS system trend data
Time per year when daily average outdoor temp is above 60 Deg F (Days)	161	Derived from 2008 historical outdoor air conditions for south eastern Pennsylvania Source: PECO Evaluator
Starting point for hot water set point reduction with outdoor air above 60 (Deg F)	148	2 degree reduction in set point
Estimated number of annual hours new set point will be used	1,932	Number of days when average outdoor air temp was above 60 in 2008 (161) x 12 hours per day to allow for colder overnights & mornings
Average re-heat energy (BTU)	1,620,000	Average flow rate (240 GPM) x average delta-T (13.5 Deg F) x constant (500)
Left Blank	Left Blank	Left Blank
Steam cost per MLb	$7.570	Calculated incremental average cost per MLb of steam from last 5 bills supplied by Hospital

COST & SAVINGS ANALYSIS		RATIONALE
Converted to steam usage (MLbs)	1.4	Average re-heat energy (1,620,000 BTU) / constant (1,198,000) NOTE: Assumes perfect heat exchanger efficiency (makes savings estimate more conservative for now)
Total steam usage with outdoor air temperature > 60 Deg F (MLbs)	2,613	Average steam usage (1.4 MLbs) x hours per year > 60 Deg F (1,932)
Target Improvement to delta-T temperature (Deg F)	2	Conservative estimate starting point, further study needed to determine
New total steam usage with lowered set point (MLbs)	2,226	Average flow rate (240 GPM) x new average delta-T (13.5 Deg F - 2 Deg F) x constant (500) / constant (1,198,000) x hours (1,932)
Potential cost savings ($)	$2,930	Steam saved (2,613 MLbs - 2,226 MLbs) x cost per MLb of steam ($7.57)
Cost to implement ECM ($)	$1,000	Programming change through the BAS system
Simple payback (Years)	0.3	ECM implementation cost ($500) / annual cost savings ($2,930)
CO_2 Saved (Tons)	12	Steam savings (2,613 MLbs - 2,226 MLbs) x constant (1,198,000) to convert to BTU / constant (100,000) to convert to therms of gas x plant & exchanger efficiency (50%) x constant (0.005)

Tozour Energy Services
THE POWER TO SAVE

Master ECM List

ECM #	Energy Conservation Measure Description	Annual Electric Savings (kWh)	Annual Chilled Water Savings (Ton Hours)	Annual Steam Savings (MLbs)	Annual Cost Savings ($)	Cost To Implement ECM ($)	Simple Payback (Years)	Annual CO_2 Savings (Tons)
1	AHU-6 Economizer	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2	AHU-6 Fan Speed Reduction	10,824	TBD	TBD	$668	$500	0.7	8
3	AHU-11 Economizer	N/A	17,858	N/A	$1,521	$1,500	1.0	10
4	AHU-11 Increase Return Air	N/A	5,617	285	$2,640	$9,404	3.6	11
5	AHU-11 Heat Recovery Loop	N/A	TBD	133	$1,008	$200	0.2	4
6	AHU-12 Economizer	N/A	9,890	N/A	$842	$1,500	1.8	6
7	AHU-12 Outdoor Air Reduction	N/A	3,644	125	$1,258	$1,500	1.2	6
8	AHU - 12 Heat Recovery Loop	N/A	TBD	99	$752	$200	0.3	3
9	AHU-12 Reduced Total Air Flow	9,898	TBD	TBD	$611	$500	0.8	7
10	New Reheat Reset Schedule	N/A	N/A	387	$2,930	$1,000	0.3	12
Retro-Commissioning Cost						$7,800	2.0	
Act 129 Potential Rebate					$10,600			
TOTALS		20,722	37,009	1,030	$22,830	$24,104	1.1	67

NOTE: ECM total is the total of "stand alone" measures, interacting ECMs could lower the actual total

Tozour Energy Services
THE POWER TO SAVE

RCx Scoping Study Summary

- Focus Of Scoping Study
  - AHU-6, 11, & 12
  - Reheat System
- Energy Savings Potential From:
  - Reducing amount of outdoor air brought into building
  - Reprogramming economizer mode & dampers (for free cooling)
  - Reducing total air flows when possible
  - Readjusting set points & reset schedules
- Potential Savings Picture
  - $12,230 energy savings + potential $10,600* rebate = $22,830
  - $16,304 improvement cost + $7,800 scoping study = $24,104
  - Less Than 14 Months Simple Payback

** Will vary depending on final implementation of ACT-129 rebate program*

Energy Savings Report

ECM # 5 Air Handler Refurbishment

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	First floor mechanical room & roof
Product or Process:	Air handling unit refurbishment
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Michael Phillips, Project Manager

Tozour Energy Services
THE POWER TO SAVE

Project Scope Definition

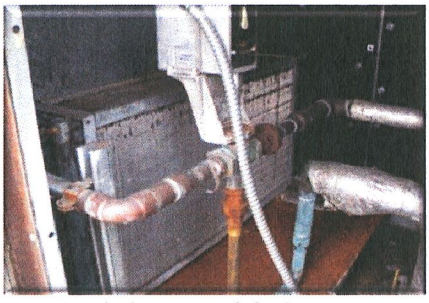
Project consists of the replacement of older fan motors with new premium efficiency, installation of VFDs in place of inlet guide vanes. Leaking duct work and coils to be repaired & cleaned or replaced. Drain pans will also be replaced. All associated mechanical & electrical labor included. Painting of units is included.

AHU refurbishment is a cost effective method to returning air handling systems to the most optimally efficient operation. Refurbishment consists of replacing older, less efficient, and defective parts with new ones. This refurbishment process will include the replacement of fan motors with premium efficient models as well as the installation of Variable Frequency Drives (VFD) in place of the existing inlet guide vanes (vortex dampers). Duct work will be sealed and drain pans will be replaced. The replacement of chilled water valves and actuators is a part of AHU refurbishment. The chilled water valves will be "Pressure Independent.

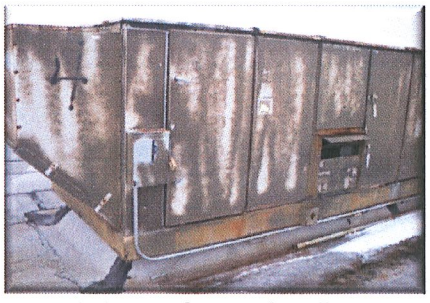
To achieve optimal results, cooling coils must operate in window of both temperature difference between their inlet and the outlet temperature and in a window of desired flow rate. As the temperature differential decreases additional water must be pushed through the coil to satisfy the load. Moving excess water is inefficient from a pumping standpoint and a low temperature differential is inefficient from a chiller operation standpoint. Losses occur when cooling coils do not consistently operate at their designed temperature drop. The vast majority of this loss could be eliminated by retrofitting the existing valves that control the water flow rate to the cooling coils with new flow control valve technology which is pressure independent.

Premium efficiency electric motors will help to optimize fan systems efficiency, reduce electrical power consumption and costs, and improve system reliability. Premium efficiency motors run cooler, last longer, and require less maintenance than the existing standard efficiency motors. Premium efficiency motors can be as high as 95% efficient as opposed to standard efficiency motors of 78% to 88%. Premium efficiency motors are also designed to operate well at varying speed allowing variable Frequency Drive (VFD) Variable speed operation allows the air handling system to satisfy space requirements, while consuming minimal electrical energy

Existing Conditions



Existing rusted drain pan



Existing rooftop air handler #4



Existing AHU-3 inlet guide vanes

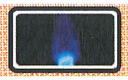
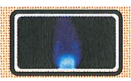
Energy Savings Report

ECM # 5 Air Handler Refurbishment

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	First floor mechanical room & roof
Product or Process:	Air handling unit refurbishment
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Michael Phillips, Project Manager

Tozour Energy Services
THE POWER TO SAVE

Cost & Savings Analysis - Savings calculated by the Trace 700 building model simulation program

	Installation Cost	$91,163	
	Reduction in Electric Consumption	40,471	kWh
	Reduction in Electric Demand	8	kW
	Reduction in Natural Gas	144	dTh
	Electrical Consumption Cost	$0.1645	/ kWh
	Electrical Demand Cost	$0.00	/ kW
	Natural Gas Cost	$12.29	/ dTh
	Annual Energy Savings	$8,424	
	Annual Operational Savings	$0	
	Annual Total Savings	$8,424	
	Pay for Performance Incentive	$0	
	Simple Payback - No Incentive	10.8	Years
	Simple Payback with P4P Incentive	N/A	Years
	Reduction in CO_2	38	Tons
	Equivalent Additional Trees	188	Trees
	Equivalent Reduction in Automobiles	7	Cars

Suggested Actions

- Contact your supplier to obtain drive efficiency as a function of motor operating speed or drive power output.
- Use this information to accurately determine the energy savings due to the use of ASD versus throttle or damper flow control. When ASD part-load performance values are not readily available, use the values given in Table 1.

Resources

U.S. Department of Energy—For additional information on motor and motor-driven system efficiency, and to download the MotorMaster+ software tool, visit the BestPractices Web site at www.eere.energy.gov/industry/bestpractices, or contact the EERE Information Center at (877) 337-3463.

National Electrical Manufacturers Association (NEMA)—Visit the NEMA Web site at www.nema.org for information on motor standards, application guides, and technical papers.

Adjustable Speed Drive Part-Load Efficiency

An adjustable speed drive (ASD) is a device that controls the rotational speed of motor-driven equipment. Variable frequency drives (VFDs), the most common type of ASDs, efficiently meet varying process requirements by adjusting the frequency and voltage of the power supplied to an AC motor to enable it to operate over a wide speed range. External sensors monitor flow, liquid levels, or pressure and then transmit a signal to a controller that adjusts the frequency and speed to match process requirements.

Pulse-width modulated (PWM) VFDs are most often used in variable torque applications in the 1 to 1,000 hp motor size range. For centrifugal fans or pumps with no static lift, the fluid or air flow provided varies directly with the pump or fan rotational speed. The input power requirement varies as the cube or third power of the speed ratio (see Figure 1). Small decreases in equipment rotating speed or fluid flow yield significant reductions in energy use. For example, reducing speed (flow) by 20% can reduce power requirements by approximately 50%.

$$hp_2 = hp_1 \times (RPM_2 / RPM_1)^3 = hp_1 \times (Flow_2 / Flow_1)^3$$

Where:
hp_1 = driven-equipment shaft horsepower requirement at original operating speed
hp_2 = driven-equipment shaft horsepower requirement at reduced speed
RPM_1 = original speed of driven equipment, in revolutions per minute (RPM)
RPM_2 = reduced speed of driven equipment, in RPM
$Flow_1$ = original flow provided by centrifugal fan or pump
$Flow_2$ = final flow provided by centrifugal fan or pump

Figure 1. Power requirement for centrifugal loads

Determining Energy Savings

To establish the energy savings that are possible when an ASD is applied to a variable torque load, you must determine the load duty cycle, or percentage of time that the fan or pump operates at each system operating point. You must also know the efficiency of the variable speed drive and the drive motor when the motor is operating partially loaded and at a reduced speed to satisfy variable flow requirements.

Variable and constant torque loads are expressed in terms of the shaft horsepower supplied by the motor. A motor "load factor" is the load imposed upon the motor by the driven equipment divided by the motor's full output rating. The load on the ASD is the actual power supplied by the device (shaft horsepower divided by the motor efficiency at its load point) divided by the rated output power. Manufacturers can provide efficiency values for ASDs as a function of operating speed or load for both variable torque loads (centrifugal fans and pumps) and constant torque loads (cranes, hoists, and conveyors).

When considering electronic PWM ASDs, you may use Table 1 to obtain efficiency values for drives of various ratings that supply power to motors connected to either variable or constant torque loads.

Table 1. PWM ASD Efficiency as a Function of Drive Power Rating[1]

Variable Speed Drive hp Rating	Efficiency,%						
	Load, Percent of Drive Rated Power Output						
	1.6	*12.5*	*25*	*42*	*50*	*75*	*100*
3	31	77	86	90	91	93	94
5	35	80	88	91	92	94	95
10	41	83	90	93	94	95	96
20	47	86	93	94	95	96	97
30	50	88	93	95	95	96	97
50	46	86	92	95	95	96	97
60	51	87	92	95	95	96	97
75	47	86	93	95	96	97	97
100	55	89	94	95	96	97	97
200	61	91	95	96	96	97	97
400	61	91	95	96	96	97	97

1. These efficiency values may be considered representative of "typical" PWM ASD performance. There is no widely accepted test protocol that allows for efficiency comparisons between different drive models or brands. In addition, there are many ways to set up an ASD that can affect the operating efficiency. *Source: Safronics, Inc.*

ASD efficiency decreases with decreasing motor load. The decline in efficiency is more pronounced with drives of smaller horsepower ratings. As shown in the following example, this reduction in efficiency is not as detrimental as it first seems.

Example

Consider an adjustable speed drive coupled to a motor that delivers 20 hp to an exhaust fan when operated at its full rated speed. At 1/4 of its rated operating speed, the fan delivers 25% of its rated airflow, but requires only 1/64 of full-load power. Even with the low drive efficiency of 47%, with adjustable speed operation the power required by the fan and the VFD is only 0.66 hp.

$$hp_{25\%} = (20\ hp \times (1/4)^3 / (47/100)) = 0.66\ hp.$$

Note: This example does not account for the efficiency at each load point for the fan drive motor.

Remember that the system efficiency is the product of the ASD efficiency, the motor efficiency at its load point, and the driven equipment efficiency ($E_{system} = E_{ASD} \times E_{motor} \times E_{Equipment}$). Efficiencies for integral horsepower NEMA Design A and B motors at full and part-load can readily be obtained from the U.S. Department of Energy's MotorMaster+ 4.0 software tool. Efficiencies for driven equipment must be extracted from the appropriate pump or fan performance curves.

BestPractices is part of the Industrial Technologies Program Industries of the Future strategy, which helps the country's most energy-intensive industries improve their competitiveness. BestPractices brings together emerging technologies and best energy-management practices to help companies begin improving energy efficiency, environmental performance, and productivity right now.

BestPractices emphasizes plant systems, where significant efficiency improvements and savings can be achieved. Industry gains easy access to near-term and long-term solutions for improving the performance of motor, steam, compressed air, and process heating systems. In addition, the Industrial Assessment Centers provide comprehensive industrial energy evaluations to small- and medium-size manufacturers.

FOR ADDITIONAL INFORMATION, PLEASE CONTACT:

EERE Information Center
1-877-EERE-INF
(1-877-337-3463)
www.eere.energy.gov

Industrial Technologies Program
Energy Efficiency
and Renewable Energy
U.S. Department of Energy
Washington, DC 20585-0121
www.eere.energy.gov/industry

A Strong Energy Portfolio for a Strong America

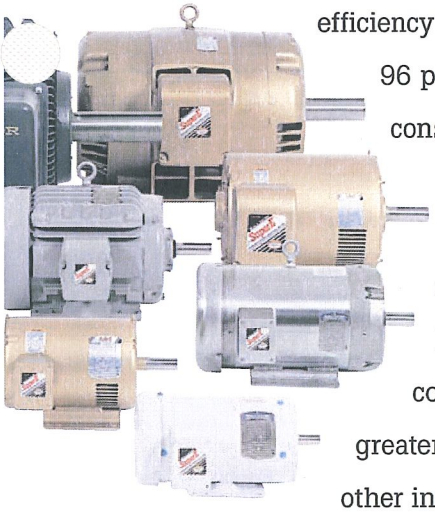
Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

DOE/GO-102008-2617
June 2008

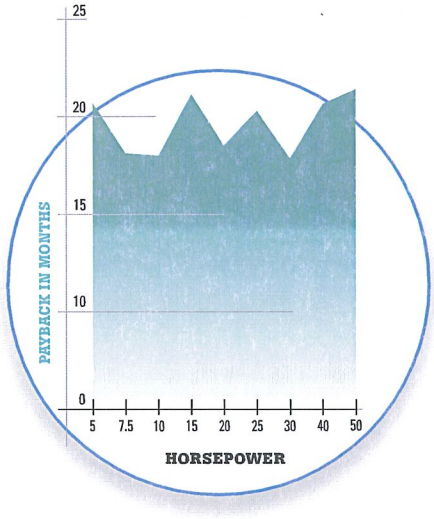
efficiencies exceed both EPAct standards and the average efficiency of motors in use today.

Premium Efficiency Pays for Itself

To understand what a motor really costs, compare initial purchase price with the cost of the electricity it uses over its working lifetime. Often, too much attention is paid to purchase price. For most motors, this initial cost represents less than two percent of its lifetime cost. Electricity accounts for nearly 98 percent. Baldor Electric Company's motors and drives save customers money every minute they operate. Whether it's lower energy costs or greater reliability, these savings go straight to the bottom line. Baldor is the industry leader in overall efficiency ratings. Better than 96 percent of the energy consumed by some of Baldor's Super-E motors is converted to mechanical work. The Baldor Super-E runs cooler and longer with greater reliability than any other industrial motor. When you consider that a typical 50 horsepower motor costs over $25,000 to operate continuously in a year, it's easy to see how just a few percentage points of higher efficiency can quickly reduce electricity costs. Even seemingly modest percentage point differences in efficiency ratings can yield substantial electricity cost savings when the motor is operating continuously every day.



Payback And The Baldor Super-E



Payback is the time (in months) it takes for the cumulative energy savings to equal the additional cost of a new Super-E motor. Payback will vary depending on the motor's use.

1998

CEE

Baldor Super-E motors are first to meet new CEE efficiency standards.

1998

Plant Engineering PRODUCT of the YEAR

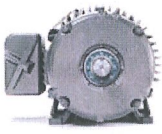
Baldor's Standard-E® line earns Product of the Year recognition from the readers of *Plant Engineering*.

1999

INVERTER READY PER NEMA STD MG1 PART 31.4.4.2

Upgraded Super-Es meet NEMA MG 1 Part 31.4.4.2 spec, making them "Inverter Ready."

2000



Baldor first to introduce Exxon POLYREX®EM bearing grease on all motors, providing superior performance and moisture resistance.

Case Studies

Peak Shaving Generators: A Win-Win Approach to Energy Savings

Baldor learned that the local electric provider for our Westville, Oklahoma, plant offered a rate schedule that provided significant savings for avoiding peak electricity usage times. Westville signed up and installed Baldor generators to subsidize power from the utility and effectively shave peak electricity demand. Westville had to effectively remove over 700 kW of demand from the utility without adversely affecting the production processes. The largest load removed was achieved by installing a Baldor 140 kW (175 kVA) trailer-mounted diesel powered generator for each of the three 100-ton air conditioning units that supply the plant with cold air.

The Baldor diesel generator sets installed in Westville were designed for both peak shaving and standby power. Therefore, these units can also supply power to critical loads in the event of an outage, which is not uncommon with the tornados and ice storms in Oklahoma.

After installing the generators and implementing several other energy efficiency ideas, electricity



Three Baldor 140kW/175kVA trailer-mounted diesel generators were installed to each of the three 100-ton air conditioning units at our Westville, OK plant. This configuration provided for the reduction of approximately 450 kW of load shaving.

costs were dramatically reduced. Based on an annual consumption of 7.1 million kWh, the kWh charge was reduced by $213,000 producing a net annual savings of over $104,000.

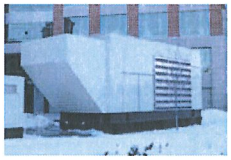
Proactive Motor Planning Lowers Energy Costs and Downtime

Skyrocketing energy prices were sapping profit margins from RMC Pacific Materials Cement Division of Davenport, California. The plant faced a pressing need to lower its electricity consumption and update its facility's energy efficiency to remain profitable. RMC recognized the potential to cut electricity consumption,

2001 — Motor Decisions Matter®

Baldor becomes sponsor.

2001



Introduced generators for peak shaving.

2002 — NEMA® Premium™

NEMA Premium® standard introduced. Baldor becomes partner.

2002



Expanded generator line to 2000 kW.

reduce expensive maintenance, and increase reliability in their processes by replacing their older motors with new, energy-efficient models. RMC Cement Division's motors are very large (up to 3000 horsepower) and fall outside the current specifications for NEMA Premium™ high-efficiency motors. Baldor worked with RMC to specify and install premium-efficient motors for the Cement Division. Baldor also assisted in developing a motor management program that compares motor replacement efficiencies, resulting in a comprehensive motor replacement strategy.

As a result, the RMC Cement Division received a $110,000 rebate from their electric utility for decreasing demand on the local energy grid through lower electricity consumption. The non-energy benefits of RMC's motor management plan included important factors like reduced plant downtime due to less need for motor maintenance. Calculations show that RMC Pacific Materials Cement Division's forward-thinking energy strategy could save them up to 3.1 million kWh in electricity usage.

2003

ENERGY STAR PARTNER

Became ENERGY STAR® Partner.

2004



Expanded Super-E energy efficient products.

Establish a Partnership with Your Electric Utility to Reduce Energy Costs

There are more than 30 U. S. electric utilities currently offering rebates to customers who buy premium efficient motors. For certain ratings, rebates can be as high as 15 percent of the purchase price for new and retrofit applications. In addition, a number of utility companies have incentive programs focused on decreasing energy use at the application level. Adjustable speed drives and soft starts qualify for these incentives.

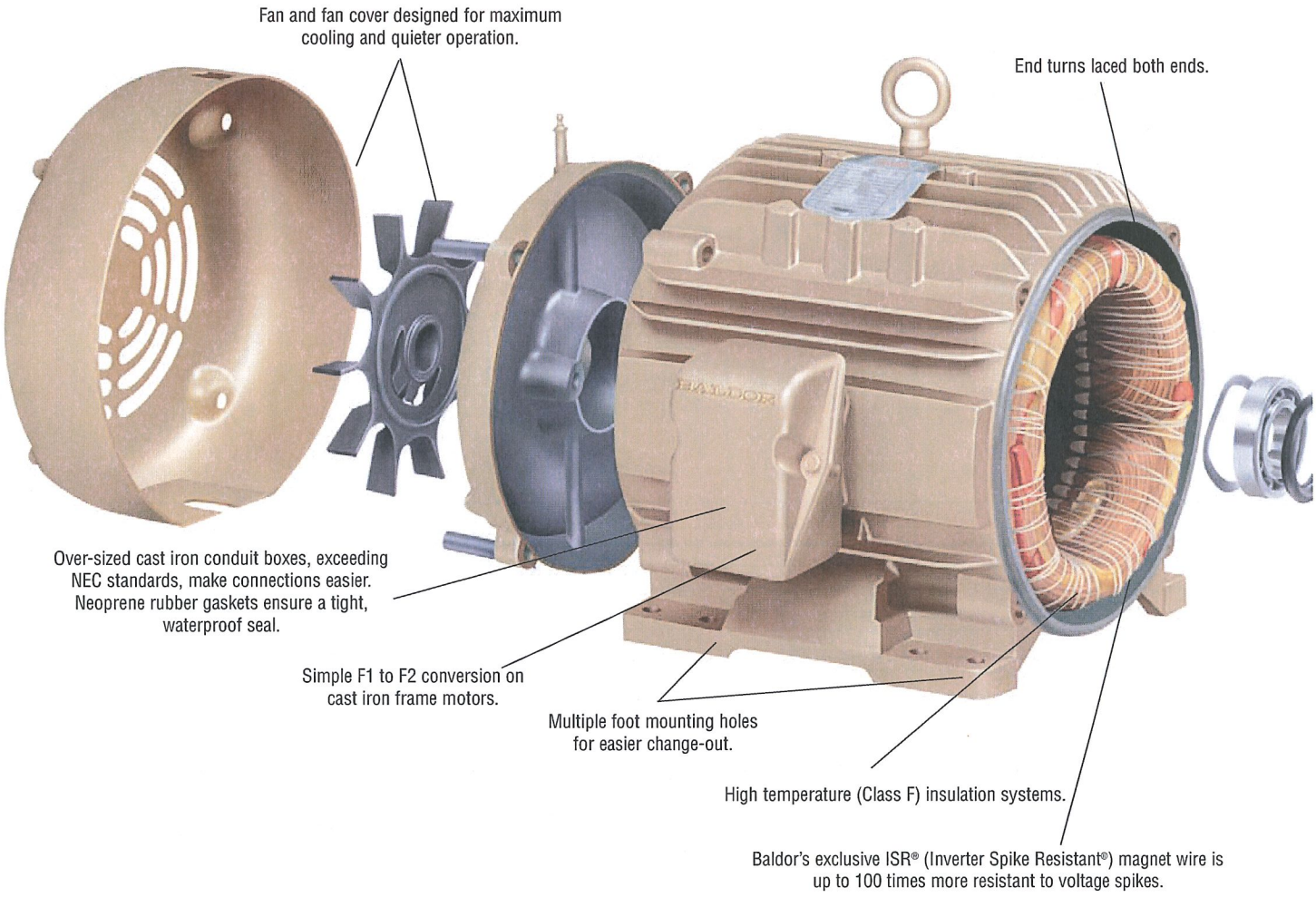
At the time of writing this brochure, the U.S. DOE offers up to $100,000 in matching funds to conduct plant surveys to determine ways to reduce energy consumption for certain industries.

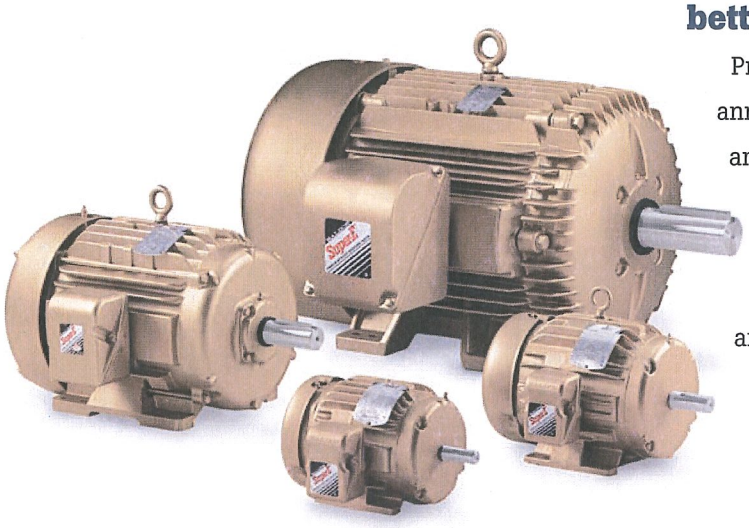
Industry should treat their electrical suppliers as a partner and work with them to understand their utility usage and investigate ways to reduce the charges. Peak demand charges from starting large motors can be reduced by adding adjustable speed drives and soft starters or simply starting large motors at different times.

Today's businesses rely on electricity for all facets of daily operation. Costly and unreliable electric suppliers can be managed through a program consisting of a reduction of electricity consumption by adding more efficient Baldor Super-E® premium efficient motors and Baldor adjustable speed drives.

Backup electrical power can be supplied by the addition of Baldor generators. Additionally, lower utility rates may be possible by use of a Baldor generator to do peak shaving or allow adoption of a consistent utility rate.

The Baldor Super-E®: Premium Efficiency Inside And Out





What makes a Baldor Super-E® better?

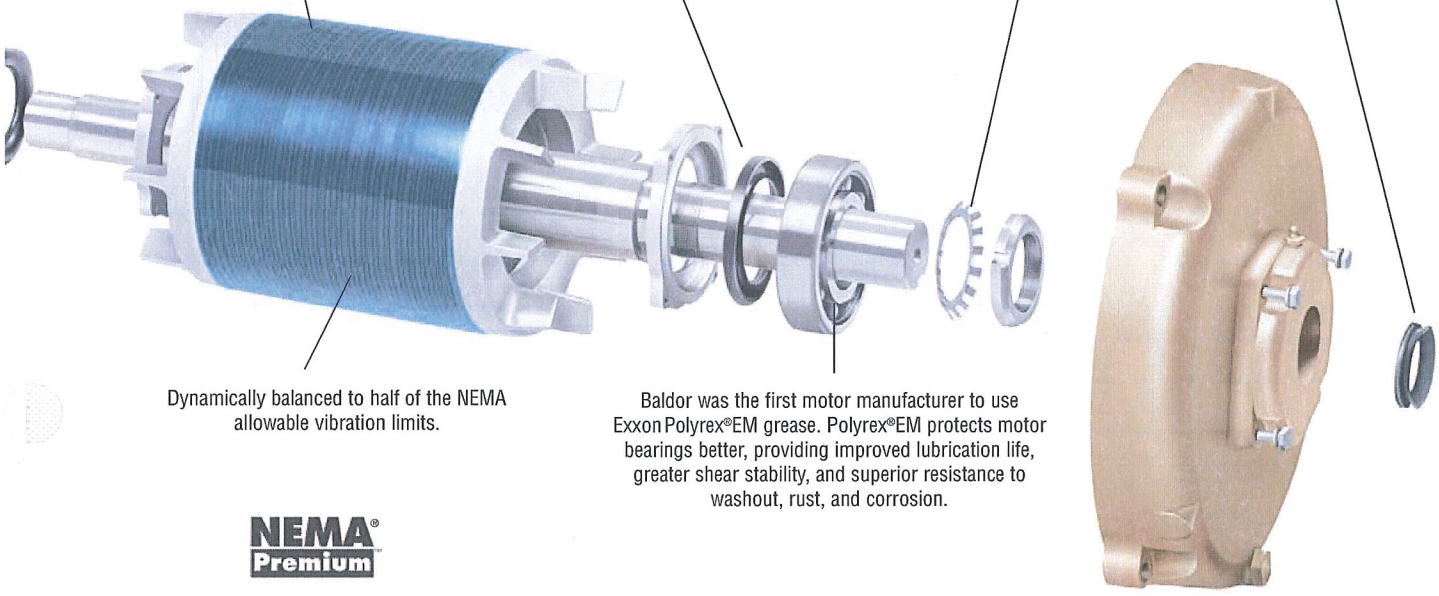
Premium-grade copper wire, more iron, annealed laminations with premium-grade steel and insulated oxide coating, superior bearings, large end rings, low-loss fans, and the expertise that enables each Super-E to run cooler and longer with better reliability than any other industrial motor.

High-pressure die cast aluminum rotor through 449T frames coated to prevent corrosion.

Neoprene rubber shaft slinger on pulley of motor prevents contaminants from entering.

Patented Lube-Lok® retainer grease seal on both ends, 250T frame and up.

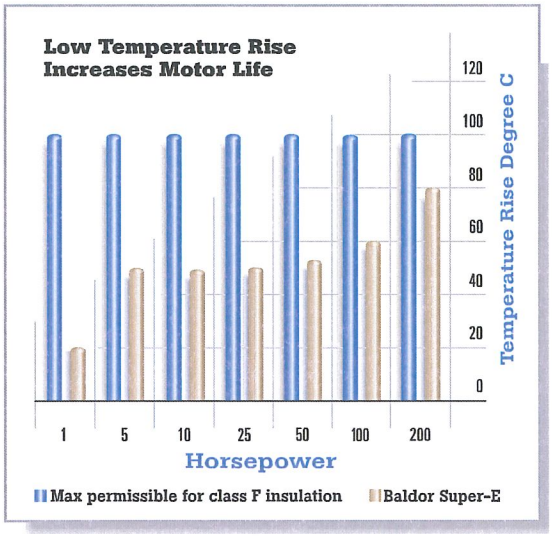
Locked bearing construction reduces endplay.



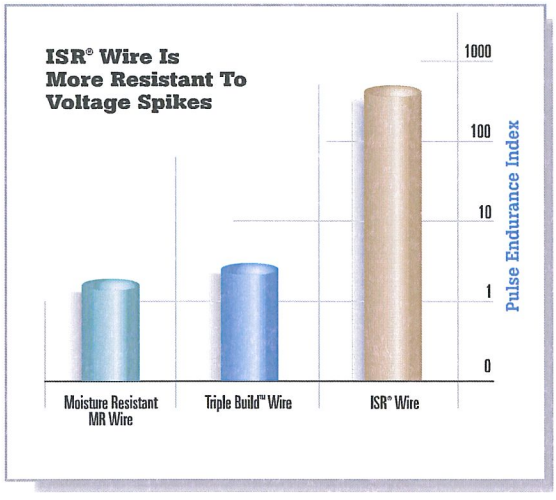
Dynamically balanced to half of the NEMA allowable vibration limits.

Baldor was the first motor manufacturer to use Exxon Polyrex®EM grease. Polyrex®EM protects motor bearings better, providing improved lubrication life, greater shear stability, and superior resistance to washout, rust, and corrosion.

NEMA® Premium

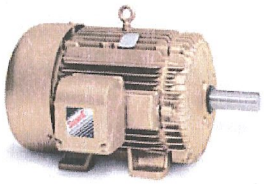


A motor that runs cooler, lasts longer.



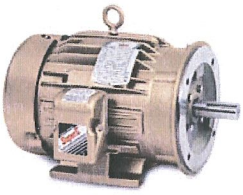
NEMA MW-35: Pulse Endurance Test
Source: Phelps Dodge Magnet Wire Company.

Super-E Motors and Baldor Drives



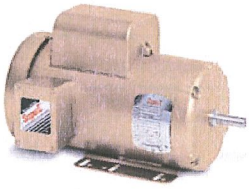
Super-E Totally Enclosed Fan Cooled (TEFC)

- Three Phase
- 1 Hp thru 500 Hp stock, to 800 Hp custom
- Enclosures: TEFC
- Foot and Face Mount
- Inverter-Ready
- Low and medium voltage including 200V and 575V



Super-E C-Face and D-Flange

- C-Face motors available from stock in most all configurations and product families
- D-Flange motors are available as custom items or through Mod Express
- NEMA or IEC style



Super-E Single Phase

- Single Phase
- 1/4 Hp thru 5 Hp stock, to 15 Hp custom
- Enclosures: TEFC and ODP
- Foot or face mount



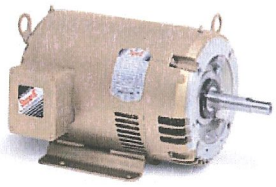
Super-E Severe Duty

- Designed for corrosive environments
- Three Phase
- 1 Hp thru 500 Hp stock, to 800 Hp custom
- Enclosures: TEFC and TENV
- Foot and face mount
- Inverter-Ready
- Low and medium voltage including 575V



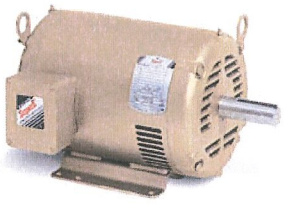
Super-E Severe Duty IEEE 841

- Three Phase
- 1 Hp thru 250 Hp stock, to 800 Hp custom
- Enclosures: TEFC and TENV
- Exceeds the IEEE 841-2001 standards for severe duty
- InproSeal® on fan and drive end shafts



Super-E Pump Motors

- Three Phase
- 1 Hp thru 50 Hp stock, to 250 Hp custom
- Enclosures: TEFC and ODP
- JM, JP and West Coast Shafts
- Inverter-Ready



Super-E Open Drip Proof

- Three Phase
- 1 Hp thru 300 Hp stock, to 1500 Hp custom
- Enclosures: ODTF, OPEN, OPSB, WPI and WPII
- Inverter-Ready
- Low and medium voltage including 200V and 575V



Super-E Explosion Proof

- Three Phase
- 1 Hp thru 60 Hp stock, to 300 Hp custom
- Enclosures: TEFC and TENV
- Class 1 Group C & D, Class II Group F & G
- U.L. approved cast conduit box standard
- Low voltage



WPI – WPII

- Low and Medium Voltage through 600 Hp stock to 1500 Hp custom
- Sleeve bearings available
- Super-E NEMA Premium® efficiency available
- Standard aluminum and copper bar rotor designs



Super-E TEFC Vertical Base

- Three Phase
- 1/4 Hp thru 75 Hp stocked
- Enclosures: OPEN and TEFC
- Normal, medium, and high thrust designs
- Standard and super efficiencies



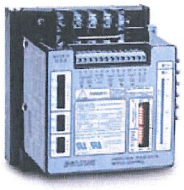
Super-E Brake Motors
- Three Phase
- 1 Hp thru 30 Hp stock
- Enclosures: TEFC and TENV
- Inverter-Ready brake connection
- NEMA standard BA dimension
- Easily convertible to C-Face



Super-E Washdown Duty
- Single and Three Phase
- 1/2 Hp thru 20 Hp stock
- Enclosures: TEFC and TENV
- Base mount, C-Face with or without base or JM pump shaft
- Available with BISSC approval
- IEC Ratings available



Super-E All-Stainless Washdown Duty
- Three Phase
- 1/2 Hp thru 10 Hp stock
- Enclosures: TEFC and TENV
- C-Face with or without base
- Labyrinth seals
- IEC Ratings available



Soft Starts
- Digital and Analog
- 1 Hp to 1000 Hp
- 230, 460 and 575 Volts
- Controls
- Combination Starters



Mini Inverter Drives
- 230 Volt 1/3 Hp thru 5 Hp
- 460 Volt 1 Hp thru 7.5 Hp
- Simple Potentiometer or Fully Programmable Operator Display
- Heavy Duty Industrial Ratings
- Dynamic Braking Option
- NEMA 1 Enclosures



H2 Drives
- Inverter, Encoderless Vector, Vector Drive and AC Servo available
- 230 Volt 3/4 Hp thru 60 Hp
- 460 Volt 3/4 Hp thru 150 Hp
- 575 Volt 3/4 Hp thru 150 Hp
- Graphical Operator Display
- PID Process Control Loop
- Ethernet Connection option

Baldor Peak Shaving Generators



Standby Generators
- Diesel Liquid Cooled, Gaseous Liquid Cooled or Industrial Diesel Liquid Cooled configurations
- 20 kW to 2,000 kW
- Superior quality weather protective sound attenuating enclosures
- Extremely reliable alternators comply with NEMA, IEEE and ANSI standards
- Components comply to UL, CSA and NFPA 110 standards



Towable Generators
- Powered by industrial grade John Deere and Isuzu diesel engines
- 20 kW to 200 kW...custom built to 2,000 kW
- Available with or without heavy-duty trailers
- Heavy 12-gauge steel enclosure construction with sound attenuation for ultra-quiet operation
- Proven brushless alternator for long life and low maintenance
- Automatic safety shutdowns

Baldor Drives Provide Application Efficiencies

In many instances, the greatest potential for energy savings lies in the overall design of the application. The U.S. Department of Energy has indicated that application and process improvements yield the highest energy savings. In some applications, savings can be as much as 60 percent. For example, heat and air systems can be made more efficient by pairing a Baldor premium efficient motor with an adjustable speed drive (ASD). The savings result from the ASD automatically adjusting the motor speed to maintain an appropriate temperature and airflow.

What is the energy savings potential from using Baldor ASDs in other applications? According to the Wisconsin Center for Demand-Side and Research, many applications for pumps and compressors could deliver savings up to 25 percent; fans, blowers, and centrifugal refrigeration systems add up to 35 percent, and boiler fans and feedwater pumps as high as 50 percent in energy savings.

Baldor's broad line of drive products for fan and pump applications, soft starts, and line regenerative AC drives provide our customers with a variety of energy saving solutions.

The Fastest Way to Calculate Payback from Electricity Savings

How long before the electricity savings from a premium efficiency motor equal or exceed your cash outlay to purchase it? The answer depends on how the motor is rated, how it is used, and the



cost of electricity per kWh. Although a premium efficiency motor costs more than a standard motor, users soon recover that cost and more. BE$T (Baldor Energy Savings Tool – version 2.0), an energy savings program, included free with this brochure, makes the calculation easy. Cost savings and payback time frames from the addition of an adjustable speed drive can be calculated as well. In a single motor mode, the motor analysis section of BE$T 2.0 compares the annual operating costs of your motors with a Baldor Super-E premium efficient motor and a Baldor Standard-E® based on its ratings and operating cycles, giving you a financial summary of the annual savings and payback in months for each. The ASD analysis compares the use of an Adjustable Speed Drive to various mechanical means of flow control in pump or fan systems, calculating annual cost of operation, savings potential, and payback. In multi-motor mode, BE$T 2.0 is powerful enough to perform a complete plant analysis and provide a complete project summary. The BE$T 2.0 program can also factor in rebates and make the payback calculation using motor rewind cost as an offset.



Simple facility surveys can lead to identification of the age and efficiency of the motor population and can lead to a motor management strategy designed to increase plant uptime and productivity (often worth 5-8 times possible energy savings). Based on their usage and efficiency, motors can be tagged to be replaced immediately with Baldor Super-E premium motors, replace on failure with Super-E (or Standard-E if hours of operation are less), or simply rewind the motor.

Ask for Baldor Electric's *Method to Reduce Energy Costs* to learn how we have been able to save nearly $1 million dollars annually in energy costs in our own manufacturing facilities. For more free software tools like the Baldor CD-ROM e-catalog where you can find our full line of premium efficiency products, just call 1-800-828-4920 or order it from our website at www.baldor.com.

Why Baldor?

More Value for the User...

It is Baldor's goal to offer more Value to our customers. How can we best do this in an electric motor? Let's look at Baldor's value formula.

$$V_p = \frac{Q_p \times S_p}{C \times T}$$

We believe that Baldor builds the best industrial motors, but it is the customer's opinion of our quality that matters here. The customer's view of Baldor's service is also important and includes the ability to furnish accurate information, literature, websites, and manuals, etc. Cost not only includes purchase price, but also cost of operation, service, shipping, parts, etc. Time deals with how long it takes to receive a motor, an answer, or a matter resolved.

How do we offer this additional Value? We build motors that last longer and perform better than industry specs call for. For over 85 years, Baldor has been dedicated to providing customers with the most Value and reliability in energy-efficient industrial electric motors and drives. But to be considered as the #1 preferred motor brand, Baldor goes beyond designing and manufacturing the best motors. Other reasons are...

Baldor offers the industry's broadest line of stock motors and drives.

You can save valuable time with just one call to Baldor for all your motor and drive needs. We stock more than 6,500 different motors, drives, gearboxes, and generators plus, a broad line of servos, linear motors and drives, and MINT® motion control products.

Baldor products are available at more locations than any other brand.

Our 36 district offices across North America offer immediate availability of Baldor products to thousands of distributors in the U.S., Canada, and Mexico.

Industry's shortest lead times/ flexible manufacturing.

Baldor has the industry's shortest lead times on custom motors – as short as two weeks. Our unique FLEX FLOW manufacturing process lets us produce any order in any quantity, quickly, and efficiently.

Matched Performance™

This Baldor exclusive provides lab-tested performance data on Baldor products to help customers quickly and easily match the right motor and control to get precisely the drive they need.

Continuous innovation to improve reliability.

Baldor leads the motor industry in applying new technologies and materials to improve motor reliability. In 1996, Baldor was first to introduce ISR® (Inverter Spike Resistant®) magnet wire, which is up to 100 times more resistant to voltage spikes. In 2000, Baldor was first to use Exxon's new POLYREX®EM Grease, which protects motor bearings better, providing improved lubrication life, greater shear stability, and superior resistance to washout, rust, and corrosion.

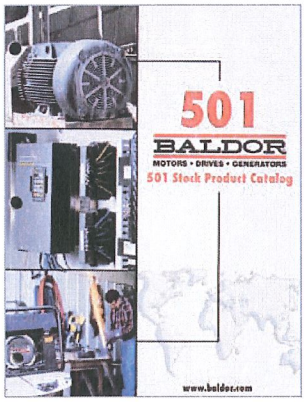
Common keypad language.

To make things easy for our customers, we developed our common-language keypad for all our controls. So you don't have to learn different languages to operate Baldor inverters, vectors, DC, or servo controls.

Industry's best information.

Only Baldor offers customers a choice of sources for product information with a wide variety of catalogs and product brochures, a CD-ROM electronic catalog, and the Baldor Web site (www.baldor.com). Or, talk to a Baldor customer service person at one of our sales offices.

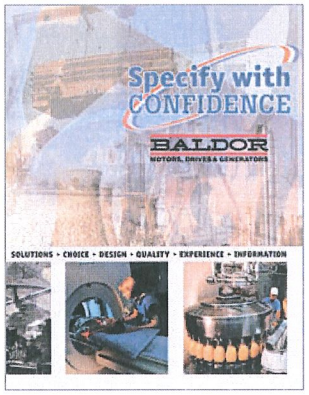
If you need fast answers to tough questions, log on to www.BaldorProSPEC.com and ask a Baldor engineer. We guarantee we will have an answer for you within one business day. Easy access to accurate information is critical and no one does it better than Baldor.



With more than 6,500 stock products and the best information available, Baldor sets the standard in the industry.

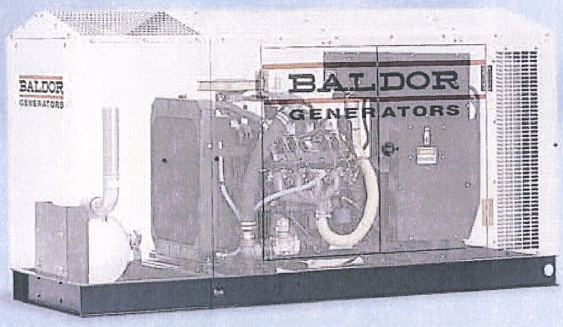


Studies conducted by leading industrial magazines and independent research companies show that Baldor is consistently the "most preferred" industrial motor manufacturer.



With more than 80 years experience as OEM and specifier product development partners, from the first call to the install, you can count on Baldor to exceed your expectations.







BALDOR®

MOTORS • DRIVES • GENERATORS

The Answer for an Energy Driven Economy

P.O. Box 2400 • Fort Smith, AR 72902-2400 U.S.A.
1-800-828-4920 • Fax (479) 648-5792
International Fax (479) 648-5895
www.baldor.com

Made in the

ENERGY STAR PARTNER

©2005 Baldor Electric Co.
BR458

Printed in the USA
7/05 AGI 25,000

8. Air Distribution Systems

Revised April 2008

8.1	**Overview**	**2**
8.2	**Air-Handling System Types**	**3**
	Constant-Volume Systems	3
	Variable Air Volume Systems	5
8.3	**Air-Handling Components**	**6**
	Fans	7
	Filters	7
	Ducts	9
	Dampers	10
8.4	**Best Opportunities**	**10**
	Optimize Zone-Level Performance	10
	Convert CV Systems to VAV	12
	Rightsize Fans	14
	Install Variable-Speed Drives	16
	Modify Controls	17
	Pick Premium-Efficiency Motors	23
	Use Energy-Efficient Belt Drives	25
	Consider a Testing, Adjusting, and Balancing Contractor	26
8.5	**Summary**	**26**
Bibliography		**26**
Glossary		**G-1**

8.1 Overview

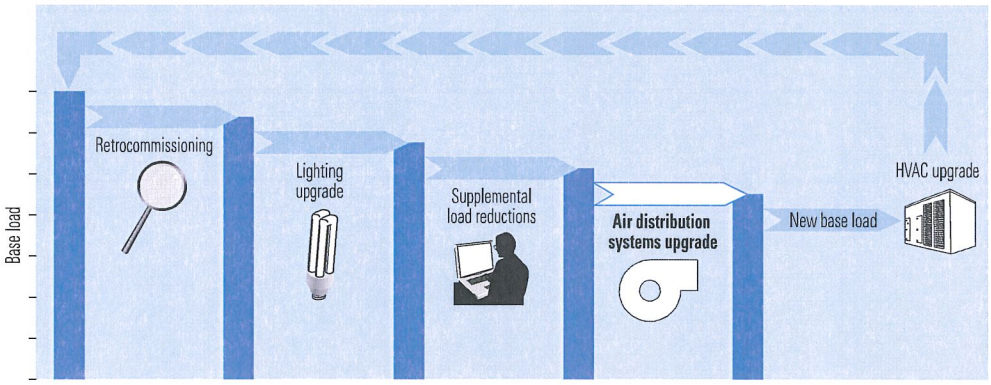
Air distribution systems bring conditioned (heated and cooled) air to people occupying a building, and therefore directly affect occupant comfort. Over the last several decades, significant improvements have been made to the design of air distribution systems as well as to the way in which these systems are controlled. These improved designs and controls can result in dramatic energy savings, yet many buildings continue to rely on obsolete, inefficient systems for this critical function.

The energy savings achieved in the Retrocommissioning, Lighting, and Supplemental Load Reductions stages (**Figure 8.1**) are likely to have reduced the load on the building's HVAC system, sometimes considerably. But before evaluating the potential to replace the existing heating and/or cooling equipment with smaller and more-efficient equipment, optimize the efficiency of the air distribution system itself. Doing so may well enable even greater savings and a reduction in required heating and cooling equipment capacity.

On average, the fans that move conditioned air through commercial office buildings account for about 7 percent of the total energy consumed by these buildings (**Figure 8.2**), so reductions in fan consumption can result in significant energy savings. A U.S. Environmental Protection Agency (EPA) study found that almost 60 percent of building fan systems were oversized by at least 10 percent, with an average oversizing of 60 percent. "Rightsizing" a fan system, or better matching fan capacity to the requirements of the load, is an excellent way to save energy in air distribution systems. There are also opportunities for energy-saving improvements to the air distribution system in four other categories: adjusting ventilation to conform with code requirements or occupant needs, implementing energy-saving controls, taking advantage of free cooling where possible, and optimizing the efficiency of distribution system components. This chapter will describe the opportunities in each of these areas, but first, it is important to gain an understanding of the types of systems that are commonly encountered and the various components of air distribution systems.

Figure 8.1 The staged approach to building upgrades

The staged approach to building upgrades accounts for the interactions among all the energy flows in a building. Each stage includes changes that will affect the upgrades performed in subsequent stages, thus setting the overall process up for the greatest energy and cost savings possible. The air distribution systems stage takes advantage of the load reductions achieved in earlier stages.

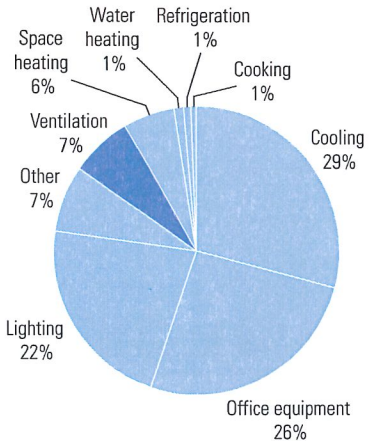


Stages of an integrated upgrade approach

Courtesy: E SOURCE

Figure 8.2: Typical electricity consumption in commercial office buildings

The power used to circulate conditioned air accounts for approximately 7 percent of commercial office building electricity consumption.



Source: U.S. Department of Energy

8.2 Air-Handling System Types

There are two types of air-handling systems: constant volume (CV) and variable air volume (VAV). In a CV system, a constant amount of air flows through the system whenever it is on. A VAV system changes the amount of airflow in response to changes in the heating and cooling load. VAV systems offer substantial energy savings and are becoming more widespread.

Constant-Volume Systems

Constant-volume systems are the simplest type of air distribution system and are installed in a large percentage of existing commercial buildings. In a CV system, when the supply fan is on, a constant amount of air flows through; there is no modulation of the fan power, no discharge dampering at the fan, and no dampering at the terminal ends of the duct runs. In its simplest configuration, a CV system serves a single space (also called a zone). A thermostat is located in the zone that senses space temperature and sends signals to the air-handling unit to provide heating or cooling based on the thermostat setting.

Reheat systems. In larger buildings, CV systems serve multiple zones with varying heating or cooling requirements. For example, a perimeter office with a vast expanse of south-facing glass may require cooling in the middle of December when the rest of the building requires heating. Constant-volume systems that serve multiple zones are typically designed with some way to vary the temperature of air delivered to each zone. To meet differing cooling loads with a CV system, *terminal reheat* or *zone reheat* is frequently added: an electric resistance element, hot water coil, or other heat source that reheats the cooled air just before it enters the room. The system is sized to provide cooling to the zone with the peak load, and all zones with less cooling load have their air reheated as it enters the zone. In humid climates, reheat systems not only provide terminal control but also strip moisture out of the supply airstream by allowing deep cooling of the primary air.

Reheat systems are as inefficient as they sound: energy is used first to cool and then to reheat the air. The thermostat in a CV-supplied zone only controls the amount of reheat applied to that zone's air. If reheat is not applied, zones will be overcooled, possibly to uncomfortable levels. CV systems without temperature reset (thermostatic control of the supply-air temperature) are now prohibited by many energy codes.

Constant-volume, variable-temperature (CVVT) systems. A CV system that adjusts or resets the temperature of the supply air is a CVVT system. As cooling loads decrease, chilled water flow is reduced (or "reset" in control system parlance) to create warmer supply air. This reset can be controlled by monitoring either the outside air temperature (outside-air reset) or the cooling needs of the warmest zone (warmest-zone reset). Although outside-air reset has simpler controls and thus may be more reliable, it bases its strategy on the frequently incorrect assumption that cooling load varies linearly with the temperature of the outside air. Solar gain through the windows and internal heat gain from people, lights, and equipment all impact the cooling load independently of the outside temperature. Warmest-zone reset, which directly monitors the indoor air temperature of interest, is more accurate: the supply-air temperature is set just low enough to cool the zone with the highest cooling load.

Because CVVT systems respond to changes in cooling load by reducing the load on the chiller, they use less cooling energy than simple CV systems do. In reheat systems, less energy is used to reheat the air because the supply air is already warmer due to the temperature reset. However, the system only responds to the peak load in each zone; large load differences among zones can still cause substantial overcooling or reheating. This is why reduction of building-skin loads with shading or window films is important: it can reduce that peak load, raise the supply-air temperature, and enable all other zones served by that air handler to use warmer supply air, use less chiller energy, and require less reheat energy. Also, for hot water reheat systems, the temperature of the hot water can be reduced based on the outside air temperature or a "coldest-zone reset" to further reduce the energy waste associated with mixing heated and cooled air.

Dual-duct systems. Often found in buildings constructed during the 1960s and 1970s, dual-duct systems are a relatively effective means of maintaining comfort, yet an extremely inefficient method of conditioning air. Dual-duct systems consist of two independent systems, one warm and one cool, that circulate air through all sections of the building via a parallel sets of ducts. Hot and cold air are mixed in local mixing boxes (also called zone dampers or, sometimes, "pair of pants" dampers) in each zone and then fed into that area. Depending on the temperature needs of the zone, the mixture of hot and cold air is adjusted until the desired temperature is reached. Unfortunately, with a dual-duct system, a volume of air that is typically much larger than the actual volume required by the building must be cooled, heated, and circulated.

In addition, the dampers in dual-duct mixing boxes frequently leak, even when they are supposed to be fully closed. During cooling operation, warm duct leakage increases the energy necessary to condition the space. The leakage is a function of construction quality and of the static pressure in the duct. Leakage ratios vary from about 3 percent to about 20 percent, with 5 percent often used as an estimate for well-built systems.

Multizone systems. Multizone systems are similar to dual-duct systems in that two streams of air, hot and cold, are mixed to produce a desired temperature. But whereas dual-duct systems mix the air in individual boxes located at each area or room, multizone systems mix air with dampers near the fans. This conditioned air is then fed to each zone so that each zone receives air at a different temperature based on its load.

There are several advantages to the multizone design. These systems require less ductwork and dampering, and therefore occupy less space, than a dual-duct system. Furthermore, the location of the mixing dampers facilitates their inspection and repair. Also, these systems tend to be quieter because the noise and vibration associated with air passing over the mixing dampers is not directly above the conditioned space. On the other hand, the disadvantages of multizone systems are the wasted energy to supply simultaneous heating and cooling and the high capital cost for the multizone dampering unit. In addition, the placement of the mixing dampers directly downstream of the main supply fan means that the air velocity will be high as it passes through them, creating significant pressure loss. The supply fan must compensate for this pressure loss to ensure adequate airflow to each zone. Finally, the dampers on the hot and cold supply streams may leak, requiring additional energy to achieve the desired temperature setpoint.

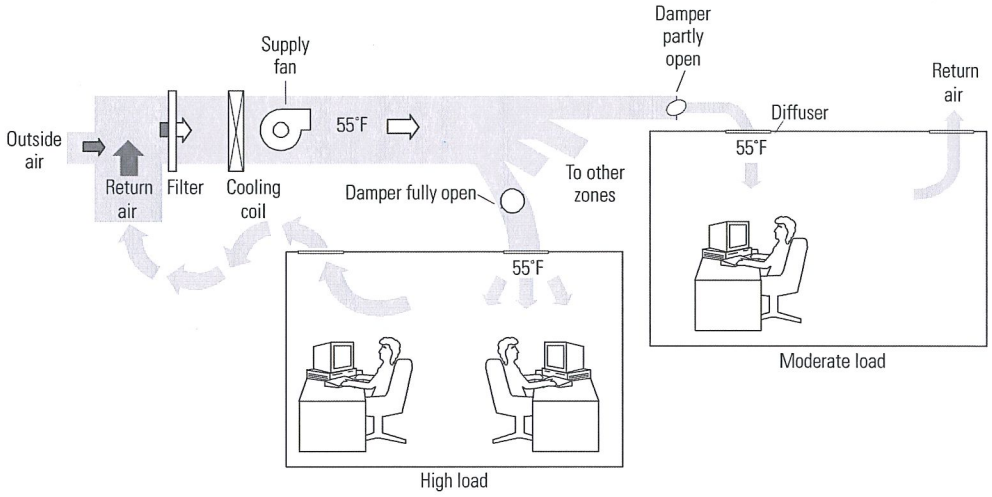
Variable Air Volume Systems

Currently available air distribution components, controls, and design strategies offer much more efficient designs than those installed and operating in many existing buildings. Today's VAV systems can handle changing load requirements by varying the amount of heated or cooled air circulated to the conditioned space in response to varying heating or cooling loads. This reduces fan power requirements, which saves energy and costs.

VAV systems work either by opening or closing dampers or by modulating the airflow through mixing boxes powered by VAV fans as loads in various zones of the building change (**Figure 8.3**). If, for example, more cooling in an area is required, the damper to that area is opened wider, increasing the flow of cold air until the desired temperature is reached. As the damper opens, static pressure in the duct drops, signaling the fan to increase air delivery. Conversely in this same example, if an area is too cool, the damper is slowly closed, reducing the flow of cold air. Used in combination with variable-speed drives (VSDs), this reduction in flow results in a reduction in the fan power needed, saving energy. Converting an existing constant-volume system to a VAV system is a popular option for many building owners, because it allows the system to turn itself down in response to changing demand.

Figure 8.3: Variable air volume system

In a VAV system, dampers control the flow of chilled air to respond to changes in cooling load.



Note: F = Fahrenheit.

Courtesy: E SOURCE

A proper conversion to a VAV system includes changing constant-volume dampers to operate in variable-volume fashion, which typically reduces fan horsepower requirements by 40 to 60 percent. Conversion from constant to variable volume can be complicated in certain circumstances due to nonmechanical factors such as:

- If the existing zone dampers are located in difficult-to-access spaces;
- If the space has a hard ceiling (typically with undersized metal access panels used to reach the mixing dampers for service);
- If the spaces to be converted have a "concealed spline" ceiling tile system (where nearly the entire ceiling must be disassembled to get at one particular spot because all of the ceiling tiles interlock); or
- If asbestos is present in the ceiling space.

It is also possible to convert an existing constant-volume, single-zone system to variable volume without modifying the zone dampers, though careful planning and testing are required for a successful project. In this type of conversion, a VSD is installed to control supply-fan speed. The VSD is controlled by either the return air temperature or the outside air temperature. Typically, to maintain comfort, the airflow reduction range is limited in such systems to 30 to 40 percent of design flow. However, even this modest reduction in airflow can reduce fan power by more than 50 percent. An additional benefit is that, under mild temperature conditions, reheat energy will be reduced along with airflow.

As with constant-volume systems, VAV supply air temperature can be reset (raised) if loads drop enough, thus reducing chiller load as well as fan power. Such a variable-volume, variable-temperature (VVVT) system changes both the temperature and the volume of supply air as needed to achieve maximum load responsiveness while minimizing reheat. A fully loaded VVVT system moves fully chilled air, usually at 55° Fahrenheit (F), at maximum fan capacity with all terminal dampers wide open. As cooling loads drop, the terminal dampers close as necessary and the supply fan slows down. When dampers reach their minimum position, zone reheat is applied (if available). Finally, when all zones are at their minimum stops, the supply air temperature is reset (raised) so that the warmest zone will need no reheat. This has the double effect of reducing the load on the chiller and decreasing the reheat energy throughout the system. The trade-off between resetting supply-air temperature and lowering supply-air volume can be optimized for a given system, perhaps reversing the order of volume reduction and temperature reset. Due to the complexity of the control system, a high degree of expertise is required to successfully commission VVVT systems.

8.3 Air-Handling Components

The major components in an air-handling system are its fans, filters, ducts, and dampers. Each component performs a task critical to the proper operation of the system: Fans circulate the air and provide the pressure required to push it through filters, coils, ducts, transitions, fittings, dampers, and diffusers. Filters clean the air, protecting occupant health, inhibiting bacteria and mold growth, and keeping coil surfaces clean. Ducts convey the conditioned air throughout the building, distributing the air to occupants and then returning it to be conditioned and circulated again. Dampers control the flow and mix of returned and outside air through the ducts to the various parts of the building. All of these components must function well both individually and together to ensure efficient system operation and occupant comfort.

Fans

Fans are the heart of a building's air-handling system. Like a heart that pumps blood through a body, they distribute the conditioned (heated or cooled) air throughout the building. There are two main types of fans: centrifugal and axial (**Figure 8.4**).

Centrifugal fans. Centrifugal fans are by far the most prevalent type of fan used in the HVAC industry today. They are usually cheaper than axial fans and simpler in construction, but they generally do not achieve the same efficiency. Centrifugal fans consist of a rotating wheel, or impeller, mounted inside a round housing. The impeller is driven by a motor, which is usually connected via a belt drive.

Axial fans. Axial fans consist of a cylindrical housing with the impeller mounted inside along the axis of the housing. In an axial fan, the impeller consists of blades mounted around a central hub similar to an airplane propeller. As with an airplane, the spinning blades force the air through the fan. Axial fans are typically used for higher-pressure applications (over 5 inches total static pressure) and are more efficient than centrifugal fans.

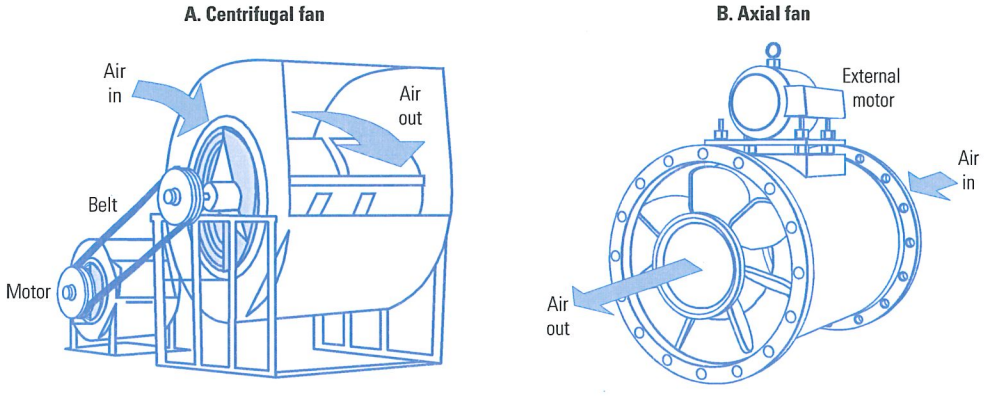
The motor of an axial fan can be mounted externally and connected to the fan by a belt. However, axial fans are often driven by a motor that is directly coupled to the impeller that is mounted within the central hub. As a result, all heat due to motor electrical losses is added to the airstream and must be removed by the cooling system.

Filters

Air filtration occupies an increasingly important role in the building environment. The high profile of ASHRAE's (the American Society of Heating, Refrigerating, and Air-Conditioning Engineers') indoor air quality standard (Standard 62.1-2007) and recent actions by the Occupational Safety and Health Administration (OSHA) have combined to give air filtration new prominence. Filtration also has a substantial impact on energy efficiency. With static pressure drops of up to 0.072 pounds per square inch (psi), filters can consume an enormous amount of fan power. As with other air-handling components, the key to efficient filtration is to consider the details, especially face velocity (airflow per unit area of filter media).

Figure 8.4: Centrifugal and axial fans

Centrifugal fans (A) are the most common fans used in HVAC applications. They are often cheaper but usually less efficient than axial fans (B).



Courtesy: E SOURCE

Filters work by capturing particles through gravity or through centrifugal collection, screening, adhesion, impingement, and/or adsorption. The *efficiency* of a filter refers not to energy efficiency, but to how well it removes particles from the airstream. *Pressure drop* is the measure that determines how much fan power is required to move air through the filter, and it varies by the square of the air speed through it. For typical HVAC-duty filters (30 percent ASHRAE dust-spot efficiency) a reasonable target pressure drop is 0.0036 psi. Dirty, thick, or poorly designed filters can have pressure drops as high as 0.072 psi—as much as the entire frictional drag of the duct system. Higher pressure also increases fan noise and vibration, duct leakage, wear and tear on the fan and other mechanical components, and a host of other air-handling ills that add real costs to fan operation. Filter performance and longevity are improved with uniform airflow, which is found upstream of the supply fan rather than downstream. Upstream filter placement also cleans the air before it moves through the cooling coils and the fan, helping to maintain their efficiency as well.

Regular filter maintenance is essential to keeping ductwork and coils clean. Dirt accumulation in ductwork can facilitate the growth of bacteria and mold, particularly if condensation occurs within the ducts. Dirt accumulation on coils impedes heat transfer, reducing system efficiency and increasing HVAC costs. Dirty filters will also reduce airflow, and may therefore reduce occupant comfort.

Visual inspection is not always an adequate way to determine whether filter cleaning or replacement is necessary. A sure-fire way to determine when filter maintenance is necessary is to install a device that measures pressure drop across the filter bank. A signal from such a device can be an input to a building automation system to alert operators when filter maintenance is required.

Commonly found filter types in commercial buildings include dry filters, bag filters, high-efficiency particulate air (HEPA) filters, electrostatic precipitators, and carbon filters.

Dry filters. Dry filters have fine strands of fabric or fiber that intercept smaller particles of about 0.5 to 5.0 micrometers. The pleats in these filters give them greater surface area, but the additional surface also lowers their face velocity. The media is contained in a cardboard frame that is generally thrown away with the fabric when it becomes dirty. These are often used as pre-filters for bag or HEPA filters.

Bag filters. Bag filters use dry media that is arranged in a long stocking shape to extend their surface area or to allow recovery of the collected material. Although commonly used in HVAC systems, bag filters are generally being replaced by rigid dry filters.

HEPA filters. HEPA filters use thin, dry media (such as paper or glass-fiber mats) with very small pores that trap superfine particulates down to 0.01 micrometer in diameter. They are heavily pleated to reduce face velocity but still contribute pressure drops of up to 0.072 psi. HEPA filters are used mostly for the demanding applications of electronics and pharmaceutical production facilities, hospital operating rooms, and facilities that generate radioactive particles. HEPA filters should be coupled with a coarser pre-filter to extend their lifetime.

Electrostatic precipitators. Electrostatic precipitators use a high voltage to ionize particles suspended in the air, then pass the airstream between charged plates that attract and accrete the charged particles. Because there is no physical impediment to the air, these filters have very low pressure drops. However, the power equipment used to create the voltage differences continuously consumes about 20 to 40 watts per 1,000 cubic feet per minute (cfm) of airflow. An efficient fan uses about 140 watts per inch of pressure drop (water gauge) for each 1,000 cfm, so the precipitator energy is about the fan-energy equivalent of 0.004 to 0.007 psi of pressure

drop. Electrostatic precipitators are usually used together with low-efficiency dry media filters that capture the largest particles and minimize the need to clean the charged plates.

This dual filter use means that electrostatic precipitator systems typically require more energy consumption and maintenance than a system with conventional filters would. One engineer estimates that electronic filters "double or triple" filter maintenance costs. The effectiveness of electronic air cleaners decreases with heavily dust-laden plates, with high-speed air, and with nonuniform air velocity. The plates that collect the charged particles must periodically be taken out of the duct and washed off, adding a maintenance step more complex than simple filter replacement. However, they do decrease the use of nonrecyclable filter components, and avoid the increasingly difficult problem of filter disposal. For overall HVAC efficiency, electronic filters usually do not make sense unless they can fulfill a specific need, such as local air cleaning in a smoking lounge.

Carbon filters. Carbon filters clean the air of gases and vapors at the chemical or molecular level. The porosity of activated, granulated carbon media is such that large, odor-causing molecules become adsorbed as they seep through the filter. The carbon can adsorb up to half its own weight in gases, which can then be driven off by heating, allowing the carbon to be reused. Carbon filters are not common in typical commercial buildings, unless there is a need to remove persistent sources of odor, such as from local industry.

A common metric for filter performance is the minimum efficiency reporting value (MERV), a rating derived from a test method developed by ASHRAE. The MERV rating indicates a filter's ability to capture particles between 0.3 and 10.0 microns in diameter. A higher MERV value translates to better filtration, so a MERV-13 filter works better than a MERV-8 filter.

Ducts

Like the arteries and veins in the human body, ducts convey the conditioned air from the air-handling unit out through the building and return it back to be conditioned again (or exhausted from the building). They are usually constructed of sheet metal and are insulated.

Ductwork can either be round or rectangular. Rectangular duct material used to be cheaper and more common than round, but the trend these days is to use a spiral version that is fabricated at local manufacturing facilities to the sizes and lengths required for each job. Spiral duct construction is similar to that of a paper drinking straw; a long strip of metal is wrapped around itself in an overlapping, continuous pattern. Spiral ductwork can be fabricated in round or oval cross-section designs. Spiral ducts tend to be less expensive than rectangular and are characterized by lower pressure drop, reduced heat gain or loss (due to the reduced surface area), and reduced weight. Spiral ducts can be manufactured in long lengths, and the spiral-lock seams make the ductwork more rigid. From an architectural standpoint, more new buildings are leaving the ductwork exposed as opposed to concealing it behind a T-bar ceiling, and spiral ductwork has an attractive shape and surface pattern that lends itself to this sort of installation.

Rough-surfaced duct material makes a fan work harder than smooth duct materials do. In engineering terms, the pressure loss of a duct is proportional to the friction factor of its inside skin and to the square of the air speed. The friction factor depends on surface roughness (the average height of protrusions from the surface) and, to a much lesser extent, on duct diameter, air speed, and air density. Smooth sheet metal, usually steel or aluminum, is the best material for ductwork: Rigid fiberglass ductwork suffers nearly 30 percent more pressure drop than sheet metal. The acoustic fiber lining used in many supply ducts (especially just downstream of the fan) has 40 percent more frictional resistance than smooth sheet metal.

Ducts must be properly insulated to prevent excessive energy loss. Duct insulation helps prevent the warming of chilled air and the cooling of heated air as it passes through the ducts. ASHRAE standard 90.1, the energy code governing design of new commercial buildings in many jurisdictions in the U.S., specifies duct insulation with a heat flow resistance level of as much as R-8 in some locations for ducts carrying hot or cold air. This requirement varies by jurisdiction; local energy and/or mechanical codes must be consulted. Proper choice of insulation can also help reduce the transmission of fan and motor noise from the HVAC system to the working spaces inside buildings.

Proper installation of the duct insulation is important as well. Because soft insulation is frequently used, it must be kept from compressing under duct hangers, against the floor or roof structure above, or against the suspended ceiling below. This requires adequate vertical clearance. Some brands of ductwork come complete with an insulation layer.

Dampers

Dampers modulate the flow of air through the ducts to the various parts of the building, reducing or increasing the airflow depending upon conditions. Dampers also regulate the quantity of outside air that is allowed to enter the air-handling unit and mix with return air for ventilation purposes. Dampers can be difficult to maintain and can affect occupant comfort as the space requirements change and as the air-handling system ages.

A typical commercial HVAC system has numerous dampers that alter the flow of outside air, return air, exhaust air, and supply air. An efficient air-handling system minimizes the number of dampers necessary overall and eliminates dampers or uses low-loss dampers at branch takeoffs, reducing the fan power needed to blow air past them but maintaining the capability for minor balancing adjustments. Using variable-speed drives for fan regulation can eliminate the need for fan inlet or discharge dampers.

8.4 Best Opportunities

When considering options for improving the performance of an air distribution system, it is important to remember that the purpose of having an HVAC system in the first place is to regulate the temperature, humidity, freshness, and movement of air in buildings. Accordingly, energy-efficiency retrofit projects should not undermine the system's capability to provide thermal comfort and air quality. The goal of energy retrofit projects should be to improve system efficiency while maintaining or enhancing comfort.

Although there are different ways to address air-handling system efficiency opportunities, one effective approach is to start at the conditioned space and work back to the air-handling unit. Looking at the opportunities in this order enables building operators to take advantage of downstream savings when addressing upstream opportunities. For example, repairing corroded zone mixing dampers that are stuck in the full-cooling position in a dual-duct system will provide better comfort to the occupants while also reducing the amount of cool air that the air-handling unit must provide. Fixing the zone dampers may unearth upstream opportunities to take advantage of the reduced cooling load with system control reset strategies or the installation of rightsized equipment.

Optimize Zone-Level Performance

The zone-level equipment consists of zone mixing dampers (such as dual-duct mixing dampers or VAV mixing boxes), reheat coils (hot water or electric), and the thermostats that control this

equipment in response to user preferences. As facilities age, zone-level equipment often falls out of calibration or into disrepair, impairing its ability to provide comfort and undermining overall system performance. Fixing zone-level problems can lead to more comfortable occupants as well as upstream energy savings.

Some of the most common opportunities to consider at the zone level are:

- *Recalibrate thermostats.* In systems with pneumatic controls, the thermostats periodically require recalibration (typically, every 6 to 12 months) in order to regulate space temperature more accurately. Though thermostat calibration should be checked if a comfort complaint exists, it is preferable to evaluate the thermostats on a regular basis as a proactive maintenance measure.

- *Inspect dampers.* For systems with zone dampers, periodically inspect the damper, linkage, and actuator for proper operation. In older buildings where maintenance has not been rigorous, it is likely that some of the zone dampers are frozen in position, rendering them ineffective at regulating comfort. Because evaluating and repairing nonfunctional zone dampers can be time-consuming and costly (especially in large buildings that may have hundreds or even thousands of zones), consider allocating a portion of the annual maintenance budget for this purpose to address a certain quantity or percentage of zones. For example, in a 100,000-square-foot, 10-story office building with 150 VAV zones, the maintenance budget might include time and money to evaluate 50 VAV zones per year.

- *Prevent overcooling.* In zone-level reheat systems, performance should be evaluated to keep cooling levels as low as possible. For hot water reheat systems, verify operation of the hot water reheat valve to ensure that it opens and closes in response to control system commands. Check the coil itself to confirm that water is flowing through when it is supposed to and that the coil is not clogged. Confirm the sequence of operation to make sure the reheat coil only operates when it is supposed to. For a single-duct VAV system, the reheat coil typically operates after the VAV damper has reached its minimum airflow position while the zone is calling for heat. If the reheat system is electric, verify proper operation of the coil in response to system commands. Verify the capacity of the electric coil by measuring its input power with an amp probe or true RMS (root-mean-square) power meter. Compare the calculated value with the nameplate value. If the calculated value is much lower than the nameplate value, the coil may have burned-out elements and may require replacement.

- *Disable reheat systems in summer months.* For CV reheat systems, consider whether the zone-level reheat systems can be disabled during the summer. Some facilities with electric reheat systems have successfully shut off the reheat coils at the breaker during the cooling season, leading to significant energy savings. In conjunction with this change, it may be necessary to adjust the supply-air temperature to avoid overcooling certain spaces, and it may be necessary to leave the reheat coil breakers active in certain spaces (such as interior zones) in order to maintain comfort.

- *Regulate static pressure.* Dual-duct systems typically include static balancing dampers for the hot and cold ducts (also called hot and cold "decks"). The purpose of static balancing dampers is to regulate the static pressure in the hot and cold decks in response to zone demands. Over time, these systems (consisting of a static pressure sensor, damper, actuator, and linkage) can fall into disrepair. Failure of the static balancing dampers can cause significant energy waste and discomfort. For example, if the static balancing damper for the cold deck is stuck in a nearly closed position, none of the zones will have an adequate source of cold air, leading to overheating.

Convert CV Systems to VAV

Retrofits involving conversion from CV to VAV are perhaps the most widely employed energy-saving retrofit to commercial HVAC systems, because typical airflow requirements for VAV systems are only about 60 percent that of CV systems. VAV systems also cool only the air volume required to meet demand, rather than meeting demand by simultaneously heating and cooling large volumes of air. **Table 8.1** presents cost and savings data from several large VAV retrofits.

To determine whether the existing system is VAV or CV, review the original design drawings for the HVAC system. If there is a schedule of VAV terminals in the equipment list that includes a minimum and maximum airflow (cfm) for each zone, it is a VAV system.

The conversion of an older constant-volume reheat, multizone, or dual-duct system to a modern, energy-efficient variable air volume system is a task to be undertaken with serious consideration and expert analysis. Unless the facility's management possesses expertise in the

Table 8.1: Installation cost and energy savings from variable air volume retrofits

The cost and savings of VAV retrofits vary widely, though most retrofits cost between $1 and $4 per square foot.

	AT&T Bell Laboratories, Indian Hills Complex, Naperville, IL	Lamonts Apparel Inc. (Factoria Square), Bellevue, WA	One Bellevue Center, Bellevue, WA	Fanny Allen Hospital, Colchester, VT	General American Life Insurance Co., St. Louis, MO	St. Louis Children's Hospital, St. Louis, MO	100 Market Building,[a] Portland, OR
Building size (ft^2)	1,200,000	50,000	344,715	114,000	450,000	560,000	120,000
Nominal fanpower (hp)	3,300	40	400	85	750	1,470	150
Peak flow (cfm)	600,000	44,000	n/a	58,800	n/a	n/a	132,000
Project cost							
VAV retrofit cost ($)	3,500,000	33,620	965,104	810,838	1,013,000	405,000	575,000
Utility rebate ($)	0	26,167	814,793	552,666	0	0	0
Net cost ($)	3,500,000	7,453	150,311	258,172	1,013,000	405,000	575,000
Cost per square foot ($/$ft^2$)	2.90	0.67	2.80	7.10	2.30	0.70	4.80
Cost per nominal fan hp ($/hp)	1,060	840	2,412	9,539	1,350	275	3,833
Cost per peak cfm ($/cfm)	5.80	0.80	n/a	13.80	n/a	n/a	4.40
Project savings							
Fan energy savings (kWh/year)	15,000,000	97,456	2,052,391	1,336,592	7,146,974	2,416,160	2,000,000
Fan power savings (kW peak)	900	n/a	234	255	n/a	n/a	200
Energy savings ($/year)	1,200,000	9,211	79,111	129,086	248,000	138,000	80,000
Payback with rebate (years)	2.9	0.8	1.9	2.0	4.1	2.9	7.2
Payback without rebate (years)	2.9	3.6	12.2	6.3	4.1	2.9	7.2

Note: cfm = cubic feet per minute; ft^2 = square foot; hp = horsepower; kWh = kilowatt-hour; n/a = not available; VAV = variable air volume.
a: In this project, TRAV control logic by Microgrid/Hartman was utilized to control the VAV systems. The cost for this project includes fees for design, project management, contractor management, and commissioning.

Courtesy: E SOURCE

conversion of CV systems, this would require the services of an engineering firm or an HVAC controls contractor. In some cases, the local energy utility may be able to provide technical assistance and incentives to help evaluate and implement the project.

The three factors that affect the feasibility of implementing a VAV retrofit are the implementation cost, the annual energy cost savings, and the building owner's minimum attractive rate of return. Surprisingly, in the case of VAV retrofit projects, the most volatile term in the cost-effectiveness equation is the implementation cost, because of the number of factors that influence the effort required to complete the retrofit. The difference between high and low energy cost savings, even when estimated using the simplest of methods, will not typically vary by more than a factor of two. On the other hand, the implementation cost can vary by a factor of ten or more depending on the characteristics of the HVAC system to be converted and the installation conditions. In certain circumstances, it will not be cost-effective to convert to a VAV system. The following factors provide an indication of whether a specific conversion project is likely to be straightforward (and therefore relatively low cost) or to present challenges that will make it more expensive.

Building-level factors

- Consider what type of access the contractor will have to the zone dampers. For example, will the contractor have to work in cramped or inaccessible spaces to access a multizone system? Check the equipment accessibility of dual-duct systems where the zone dampers are located out in the conditioned space: Is the ceiling a T-bar system that facilitates access for equipment installed above the ceiling, or is it a "hard-lid" system that makes it more challenging to access the dampers?
- If the building includes asbestos-containing materials, they may either have to be removed or contained during the retrofit process, which can add significantly to project cost.

System-level factors

- In an existing CV system, check the age and condition of the existing zone dampers and actuators. If they are in good condition, it will make the conversion easier than if the contractor also has to repair components along the way. It would not make sense to make costly changes to a system that has maintenance issues that would prevent it from functioning properly.
- For a dual-duct or multizone system, see whether the existing hot and cold dampers are controlled by one or two actuators. Converting these systems to VAV usually requires two actuators so that the hot and cold air supply can be regulated independently. Having two actuators already installed usually leads to a simpler, less expensive conversion. It is possible to add a second actuator if there is only one, but it will add cost and complexity to the project.
- If the existing system is in poor condition, a major portion of the total project cost for a VAV conversion can be attributed to system maintenance and replacement as opposed to an energy retrofit project. The energy savings are a benefit of such a conversion, but the focus ought to be how to make the HVAC system meet the occupants' thermal comfort requirements.

When soliciting bids from contractors, it can be helpful to look for nearby buildings that are similar in age and design to the building in question and determine whether VAV conversion has been implemented. Often, several similar buildings that used the same design and construction team would have been built in a city during the same era. As a result, the energy retrofit solutions that worked (or did not work) at one building might be applied to another. And a contractor who

has already converted similar HVAC systems in previous projects will likely be able to provide a more competitive price than ones who will need to figure it out as they go.

Once the conversion is complete, have the new system commissioned by an independent contractor as part of the retrofit project to ensure that everything operates according to plan.

Rightsize Fans

If HVAC fans are oversized, replacing them with ones that are correctly sized—"rightsizing" them—can be cost-effective. Rightsizing can be implemented separately or in combination with the installation of premium-efficiency motors and VSDs. In general, rightsizing with a premium-efficiency motor, energy-efficient belts, and a VSD is the best alternative. A rightsized system saves energy costs, but there are other advantages as well:

- *Lower first costs.* Because the capacity required from the fan system is reduced, the system can be more accurately tailored to the new airflow requirements. By installing smaller, more energy-efficient equipment that meets these requirements, first costs are also reduced.
- *Comfort.* If the fan system supplies too much air to occupants, energy is wasted and comfort can be compromised. Too much air can result in disturbing drafts, increased humidity, and noise.
- *Longer equipment life.* Prolonged operation at very low speed of an oversized motor with a VSD can reduce the useful life of the motor and associated equipment. Properly sized equipment will be more suited to operation at reduced capacities.

As a first step, the opportunity for rightsizing an air distribution system can usually be determined by building maintenance staff. Once an opportunity has been identified, however, it is usually necessary to hire an HVAC engineer to verify it, to conduct a more detailed analysis, and to make recommendations for optimizing the system.

The approach to assessing the potential for rightsizing varies depending upon whether the existing system is constant or variable volume. Either way, though, it is critical that the proper amount of outside air is maintained to ensure occupant health and comfort. Consult local building codes for information about required outside-air quantities.

Diagnosing oversized fans in VAV systems. Although VAV systems are more energy efficient than CV systems, the potential for rightsizing may still exist. Building maintenance staff may be able to determine whether the VAV fans are oversized by using one of three methods: measuring fan-system static pressure, measuring the fan-motor current draw (amperage), or checking the fan-control vanes and dampers.

The first method is to measure the static pressure of the main supply fan system. It is best to get a baseline measurement on a hot, humid day. Make sure that all fan vanes and dampers and all VAV boxes are fully open. Compare the static pressure reading with the static pressure setpoint. If the reading is less than the setpoint and building occupants are comfortable, the setpoint can be adjusted to the lower static pressure.

Static pressure measurements must be taken at the same location in the distribution system as the pressure sensor that regulates system operation, usually about two-thirds of the way down the main supply duct. If such a measurement is not possible or practical, the desired setpoint can be found by gradually reducing the fan speed each day until the pressure is as low as possible but occupant space is still comfortable. This change will significantly reduce fan power requirements. Be sure to survey occupants periodically to assess comfort. It may also be necessary to restore the old setpoint

on extremely hot days. In those cases, consider having the control system programmed to automatically reset the static pressure setpoint (for more on pressure reset, see the Modify Controls section).

Next, measure the fan-motor power draw using a true RMS power meter. For a VAV system, make this measurement when the cooling system is operating under a peak load (for example, on a hot, humid day). Next, read the full-load power rating off the motor's nameplate or from the operating manual. Compare these two numbers. If the measured power is less than 75 percent of the motor's rating, the motor is oversized.

Comparisons of measured to rated current can be misleading because a motor's power factor drops when it is lightly loaded. Therefore, measuring only current does not provide an accurate estimate of motor loading. Better accuracy will be achieved by using an RMS power meter that measures voltage and current simultaneously and displays true power. Also, when comparing measured input power to nameplate power, keep in mind that 1 kilowatt = 0.746 horsepower (hp). Power meters typically display results in kilowatts, but motor nameplates in the U.S. are labeled in horsepower.

Last, check the position of the fan control vanes or dampers when the cooling system is operating under a peak load. If the vanes or dampers are closed more than 20 percent, the fan may be oversized.

Diagnosing oversized fans in CV systems. If it is not economically feasible to retrofit to a VAV system, rightsizing a CV system is generally a profitable choice. However, building maintenance staff is typically limited to just one method of determining the potential for rightsizing: measuring fan-system static pressure.

Measure the main supply fan system static pressure on a hot, humid day. Make sure that all fan vanes and dampers are fully open. If the measured static pressure is greater than the design pressure (found in building mechanical drawings), the fan is probably supplying too much air and is a good candidate for rightsizing.

Three ways to rightsize. If analysis indicates that a supply fan is oversized, considerable energy can be saved by rightsizing the fan in one of three ways:

- *Larger pulleys.* Replacing an existing belt-driven pulley with a larger one will reduce its speed, and since fan power is proportional to the cube of speed, even small speed reductions can reduce energy costs appreciably. The new pulley should operate the fan at a reduced speed that still matches peak load requirements.
- *Static pressure adjustment (VAV systems only).* Reducing static pressure in a VAV system reduces the fan horsepower consumption. By gradually reducing the static pressure setpoint to a level low enough to keep occupants comfortable, fan speed will be reduced, thereby reducing energy consumption.
- *Smaller, premium-efficiency motors.* Once the fan flow rate has been properly adjusted, the existing motor will probably be larger than necessary. Replace the existing, oversized motor with a smaller, premium-efficiency motor that matches the load. For example, rightsizing a 75-hp standard-efficiency motor to a 50-hp premium-efficiency motor could reduce motor energy consumption by about 33 percent. Some premium-efficiency motors operate at slightly higher speeds than the motors they replace. Because a fan's power consumption increases in proportion to the cube of its speed, it is important to compare the nameplate speed of the existing motor with its premium-efficiency replacement. See the Pick Premium-Efficiency Motors section.

Estimating potential savings. The expected benefits of rightsizing can be estimated using a commercially available fan analysis software program. The U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy has collected information about several such packages (www.eere.energy.gov/buildings/tools_directory/subjects.cfm/pagename=subjects/pagename_menu=materials_components/pagename_submenu=hvac_systems). This software generally requires information about the existing fan system such as:

- Operating schedule
- Type of flow control
- Duty cycle
- Motor horsepower and efficiency
- Peak flow rate
- Peak cooling coil load

Install Variable-Speed Drives

Variable-speed drives are an efficient and economical retrofit option that should be considered for all VAV systems. VSDs allow the motor speed to vary depending on actual operating conditions, rather than operating continuously at full speed. Varying a fan's speed allows it to match changing load requirements more closely, and because fan power draw is proportional to the cube of its speed, reducing speed can save a lot of energy. For example, reducing a fan's speed by 20 percent can reduce its energy requirements by nearly 50 percent (**Figure 8.5**). Installing a VSD on the fan motor allows the fan to automatically match this reduced capacity, slowing down in response to reduced demand, thereby saving energy.

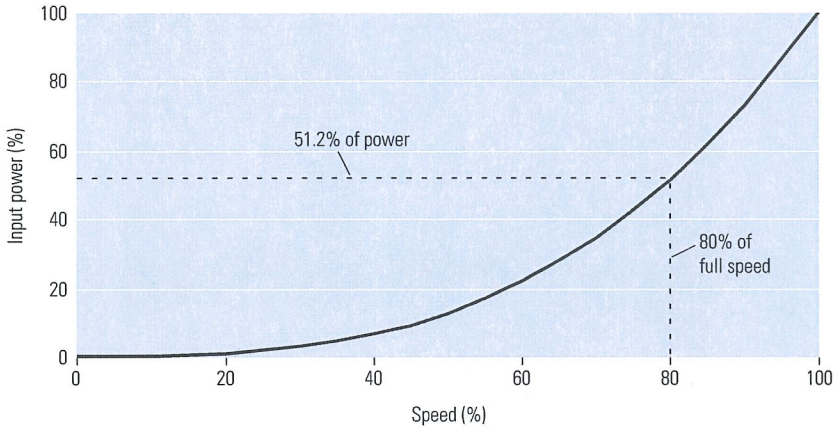
CASE STUDY: Big Savings from a VAV System Retrofit

A retrofit to the 12-story City Hall in Phoenix, Arizona, demonstrates the savings achievable by matching fan power to cooling and heating load. The building originally had a constant-volume, dual-duct system with cold deck temperature reset, supplied by four 60-hp supply-air fans and two 50-hp return-air fans. Pre-retrofit, the fan energy consumption was over 2.2 million kilowatt-hours per year. Analysis of the building's loads showed that the fans were considerably oversized, moving a constant 220,000 cubic feet per minute when the peak load actually called for only 130,000 cfm. On this basis, two of the supply fans and both return fans were disconnected, resulting in an immediate savings of over 50 percent. A bypass duct was installed around each of the disabled return fans, eliminating substantial friction losses.

The remaining two fans were converted to variable air volume by installing variable-speed drives controlled by static pressure sensors in the ducts. The interior zone dual-duct boxes were converted to VAV boxes by sealing off the connection from the hot deck and connecting a new pneumatic actuator to the cold deck damper that was operated by a zone thermostat. The new system registered average savings of 70 percent compared to constant-volume operation, with a maximum demand reduction of 78 percent. Complaints of discomfort also decreased. Based on a conservative estimate of 50 percent average annual VAV savings, the $90,000 project saved 1.7 million kWh, worth over $135,000 per year, resulting in a payback of about eight months.

Figure 8.5: Fan power input versus speed

The load on a fan motor increases as the cube of its speed. Therefore, using a variable-speed drive (VSD) to reduce speed to 80 percent of full speed reduces power consumption to just $(0.8)^3$, or 51.2 percent of its original load level. The VSD itself does consume some power, so careful assessment is necessary for any application where average fan speed will exceed 90 percent of full speed.



Courtesy: E SOURCE

A VSD is not a motor; it is an electronic device that varies the speed of a motor by changing the frequency of the electrical power between 0 and 60 Hertz. The EPA study "Variable Air Volume Systems Maximize Energy Efficiency and Profits" showed that VSDs can greatly reduce the energy used by the same fan operating under similar airflow volumes and static pressure conditions. Overall, the study indicated that VSDs provided an average energy savings of 52 percent.

VSDs make economic sense when installed on motors that operate many hours per year at fluctuating loads, and especially on larger motors. **Table 8.2** presents representative installed costs for VSDs of various sizes.

Modify Controls

Modifying the way the distribution system operates, not just the system itself or its components, can also save energy.

Optimized scheduling. An optimum start-and-stop procedure is a common-sense control philosophy that can result in significant energy savings. Normally, a system is set to automatically turn itself on and off based upon the expected occupant working hours. For example, a building's cooling system might come on at 6:00 a.m. and shut off at 7:00 p.m. Adjusting these times for varying seasons will reduce energy costs. In the spring and fall seasons, when cooling is required but the peak temperatures are typically lower than the summer peak temperatures, the system can be set to come on later in the morning and shut off earlier in the day. Of course, the system can also be shut down if the building is unoccupied.

Supply-air temperature reset. Most cooling coils are designed to deliver 53° to 55°F air to satisfy cooling requirements on the hottest day of the year. During periods of milder weather, this temperature can be automatically reset upward to improve system efficiency by reducing wasteful reheating of already cooled air. Supply-air temperature reset can be accomplished in a few different ways.

Table 8.2: Installed costs of VSDs for various size motors

Installed costs for variable-speed drives range from approximately $2,500 for a 5-horsepower (hp) drive to $16,000 for a 100-hp drive. Note that the price per horsepower declines dramatically as power capacity increases.

Motor hp	Installed cost ($)	Price per hp ($)
5.0	2,475	495
7.5	2,950	393
10.0	2,950	295
15.0	3,675	245
20.0	4,900	245
25.0	5,875	235
30.0	6,825	228
40.0	9,275	232
50.0	10,400	208
60.0	11,800	197
75.0	15,200	203
100.0	15,800	158

Courtesy: E SOURCE; data from R.S. Means Electrical Cost Data, 2007 edition

The most common reset strategy is to implement a simple proportional reset based on the outside air temperature; on a hot day, the supply-air temperature (SAT) is set to its design (or original) value, and when the weather is cooler, the SAT is increased. This is usually specified in a table that lists two outside temperatures and the corresponding SAT. For example, at 95°F outside temperature, the SAT is set to 53°F; at 65°F outside temperature the SAT is set at 68°F. The SAT is then reset proportionally between these two points. With a proportional reset system, building operating staff will often provide better comfort if they "tune" the reset parameters based on observed performance. Some buildings will require a colder SAT on mild days due to higher internal loads (people, lights, office equipment) or due to higher solar gain through windows. Conversely, buildings with efficient lighting systems and high-performance glazing may achieve good comfort with a warmer SAT at the same outside conditions.

For HVAC systems that include digital controls at the zone level, it is also possible to reset the SAT based on the "worst-case zone" approach. Under this scenario, the SAT setpoint is reset so that the zone with the greatest cooling requirement has its zone damper fully opened to provide 100 percent flow. All other zones, which have lower cooling requirements, will automatically adjust the VAV damper to maintain comfort.

For VAV systems, particularly those with VSDs installed, it is important to consider the impact of SAT reset on fan power; if the SAT is reset too high, then the energy saved due to reduced reheat will be overshadowed by increased fan power requirements.

Pressure reset. Pressure reset is a method that can yield additional energy savings in systems that have VSDs installed. Pressure and flow are related. Reducing the pressure supplied by fans also reduces the flow supplied, which in turn reduces the power required. By reducing the duct pressure by 30 percent when less air is required, almost instantaneous fan

energy savings of more than 50 percent can be achieved above and beyond the application of a VSD. The desired setpoint can be found by gradually reducing the fan speed each day until the pressure is as low as possible but occupant space is still comfortable. It is possible to have two or more pressure settings; for example, one for daytime and one for evening or one for summer and one for winter. With HVAC systems that include digital zone controls, it is also possible to implement a static pressure reset based on the worst-case zone approach described above for supply-air temperature reset. The strategy is the same: The static pressure setpoint is reset so that the zone damper in the worst-case zone is fully open. Keep in mind that, if both temperature and pressure resets are to be implemented simultaneously, some thought must be given to how these savings measures will interact.

CASE STUDY: Air Distribution System Upgrade Saves Energy, Boosts Comfort

The building known as 600 B Street is a 24-story, 334,000-square-foot, Class A commercial office facility located in San Diego. The 25-year-old high-rise facility had unreliable cooling equipment, high operating and maintenance costs, and substantial numbers of tenant complaints.

Prior to the energy-efficiency implementation, the fan systems could not provide adequate comfort on hot, humid days. The variable air volume dampers would open fully in an attempt to satisfy the space-conditioning requirements. But as the chiller plant and air-handling systems reached their capacity limits, the supply-air temperature would climb too high and the system static pressure would be too low, blowing large quantities of air that was too warm and humid to provide the required cooling effect. As a result of these problems with static pressure control, the system was drafty on hot days and noisy on cold days. Variable-speed drives were installed on the supply fans to gain energy savings and quiet the system during low-load operation, reducing tenant complaints.

To allow faster resetting of the HVAC system variables and to maximize the potential for savings, 25 percent of the VAV terminal controllers in the building were switched from pneumatic control to digital (electronic) zone-terminal control and the information from the zones was used to reset the static pressure setpoint for the air-handling units and the supply-air temperature setpoint. Ideally, all of the VAV terminal controllers would have been replaced, but the cost of doing so would have been high. The digital system is configured to reset static pressure and supply-air temperature continually based on the loads being served.

After a two-year period of measurement and verification, it was determined that fan energy was reduced by 73 percent. The 800,000 kilowatt-hours per year in electrical savings equates to about $120,000 per year in energy cost savings, resulting in a very cost-effective retrofit. Including the incentives offered by the local utility, the energy retrofit project (which included chiller plant measures in addition to the modifications to the air system) paid for itself within about three months. The indoor air quality has also improved dramatically, resulting in an 85 percent drop in tenant complaints.

As a result of the project's documented level of energy efficiency and its positive effect on occupant thermal comfort, the project was honored by ASHRAE for both the San Diego Chapter and the Western Region.

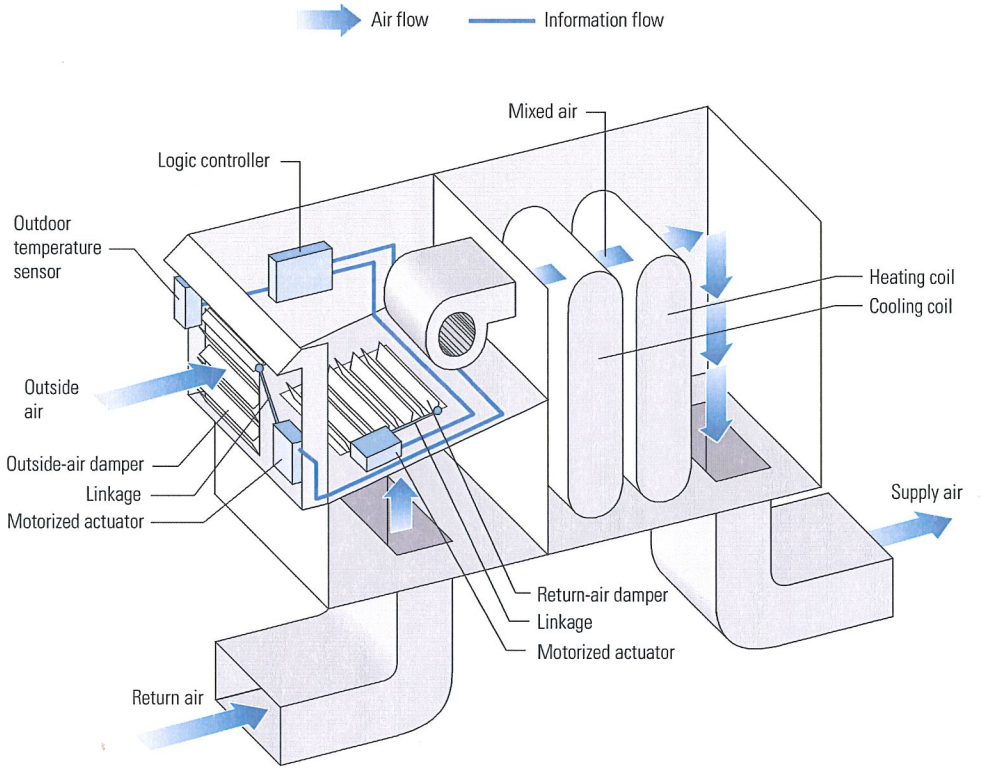
Economizer cooling. Air-side economizers consist of a collection of dampers, sensors, actuators, and logic devices on the supply-air side of the air-handling system (**Figure 8.6**). The outside-air damper is controlled so that when the outside air temperature is below a predefined setpoint, the outside-air damper opens, allowing more air to be drawn into the building. On hot days, the economizer damper closes to its lowest setting, which is the minimum amount of fresh air required by the local building code.

All economizers are not created equal. The simplest and most common type is the basic dry-bulb economizer that controls the outside-air damper based on a specified temperature setpoint. An enhancement to this approach is an enthalpy (or total energy content) economizer, which accounts for both the temperature and the humidity of the outside air and can improve the energy savings associated with the economizer by not cooling with outside air under high-humidity conditions. One of the most advanced economizer control strategies available today is a differential enthalpy system, in which two enthalpy sensors are installed (one for the outside air and the other for the return air). Under the differential control strategy, the system preferentially uses whichever air source (outside or return) has lower enthalpy when there is a need for cooling.

When the outside temperature and humidity are mild, economizers save energy by cooling buildings with outside air rather than using refrigeration equipment to cool recirculated air. A properly operating economizer can cut energy costs by as much as 10 percent of a building's

Figure 8.6: The components of an economizer

When the air outside is cooler than the return air and sufficiently dry, economizers cool buildings by bringing in outside air, thereby reducing the load on the compressor.



Courtesy: E SOURCE

total energy consumption (up to 20 percent in mild, coastal climates), depending mostly on local climate and internal cooling loads.

Economizer commissioning and maintenance are vital to proper operation and energy savings. A large number of newly installed economizers do not work properly, and their problems increase as they age. To make matters worse, malfunctioning economizers often waste much more energy than they were intended to save. If an economizer breaks down when its damper is wide open, peak loads can shoot up as cooling or heating systems try to compensate for the excess air entering the building. A computer simulation of an office building in arid Phoenix, Arizona, shows that a damper permanently stuck in the wide-open position could add as much as 80 percent to that building's summer peak load, assuming the building had enough cooling capacity to meet the much higher load resulting from cooling excessive outside air.

Demand-controlled ventilation. Many building codes in the United States base their ventilation requirements on a standard written by ASHRAE that requires that commercial buildings bring in a specified minimum amount of fresh air to ensure adequate indoor air quality. To adhere to this standard, the choice made in most buildings is to ventilate at the fixed minimum rate per person based on the building type and the assumed occupancy, which is usually the building's design occupancy. But because the number of people occupying the space at any given time can vary widely, the ASHRAE standard offers another way to ventilate based on actual occupancy numbers. This is called demand-controlled ventilation (DCV).

Because the average amount of carbon dioxide (CO_2) exhaled by a person in a fixed time period at a given activity level is well known, the concentration of CO_2 in the air inside a building is a good indicator of the number of people in a space and the rate at which the air in the space is being diluted with outside air. The more occupants a building has at any given time, the higher the level of CO_2 in the air. The ASHRAE standard allows building operators to use DCV to bring in and condition only the air necessary for the actual occupancy. In a DCV system, sensors monitor the CO_2 levels inside and send a signal to the HVAC controls, which regulate the amount of outside ventilation air that is drawn into the building. Though ASHRAE does not set a maximum allowable CO_2 concentration, the most recent version of the standard recommends that the indoor CO_2 level be no more than 700 parts per million (ppm) above the outside level, which is typically about 350 ppm.

CASE STUDY: Power Exhausts Cut Cooling Costs

The majority of conventional air-handling units are able to provide 100 percent outside air. However, at one 200,000-square-foot office building in a Boston suburb, it was noticed that air-conditioning compressors in the rooftop units operated on all sunny days, even when outside air temperature was as low as 35° Fahrenheit. The reason was that solar-heated interior air had no way to escape from the building, so even with outside air dampers wide open, the rooftop units could not provide enough outside air to cool the building without the aid of mechanical refrigeration.

The solution was to install power exhausts in the rooftop units that exhausted all indoor air when the building was in economizer cooling mode. Roughly 1,000 hours per year were found to have proper conditions for free cooling. After the installation of the power exhausts, cooling compressors only operated when the outside air temperature was above 55°F. The installation cost $75,000 and paid for itself in under four years.

DCV systems save energy by reducing the need to heat or cool outside air. The only system change is the ratio of recirculated air to outside air; fan power is usually unaffected. DCV systems can save from $0.05 to $1.00 per square foot, depending on the occupancy schedule and climate (see sidebar).

The overall cost for implementing DCV has dropped substantially in recent years, opening up new opportunities for savings and spurring changes in some building codes. Also, several HVAC equipment manufacturers now offer DCV-ready rooftop units and variable air volume (VAV) boxes. This equipment is shipped with terminals for the CO_2 sensor wires and controls that are preprogrammed to implement a DCV strategy. By limiting installation costs to the cost of mounting the sensor and running wires to the rooftop unit or VAV box (wireless models are also available), DCV-ready HVAC equipment substantially reduces the cost of implementing DCV.

Facilities that would likely reap energy savings with the use of DCV tend to have long operating hours, widely varying and largely unpredictable occupancy levels, and at least moderate annual heating or cooling loads. A large number of facilities meet this description, including grocery stores, supermarkets, big-box stores, theaters and other performance spaces, lecture halls, places of worship, sports arenas, restaurants and bars of all types, and department stores. In fact, the majority of commercial facilities that are not now using DCV are at least potential targets for the technology.

Care must be applied when planning a DCV retrofit to ensure that adequate air quality is maintained. Of paramount concern are the location and quantity of CO_2 sensors. Although it might be tempting to install a single CO_2 sensor in the return-air duct for the entire building, this could lead to situations where the average CO_2 level is acceptable but the level in specific, highly occupied spaces (such as a packed conference room) is too high. For this reason, it is typically more effective to install CO_2 sensors in each high-occupant-density or high-diversity space and use them to command the minimum position of the VAV box.

Many energy codes that permit DCV also have required minimum ventilation and airflow rates (such as 0.15 cfm per square foot). Be sure to confirm local requirements before committing to a project.

A study conducted in 2003 at Purdue University shows favorable paybacks for DCV in a variety of buildings. The study investigated four types of buildings—a restaurant, a retail store, a

RESOURCES: Demand-Controlled Ventilation Design Tools

Several free tools are available to evaluate potential energy savings from demand-controlled ventilation:

- Carrier provides the Hourly Analysis Program (www.commercial.carrier.com/commercial/hvac/general/1,,CLI1_DIV12_ETI496,00.html?SMSESSION=NO).
- Honeywell has the Savings Estimator (http://customer.honeywell.com/Business/Cultures/en-US/Products/Applications+and+Downloads/Economizer+Logic+Module+(W7212)+Simulator+and+Demand+Control+Ventilation+Savings-Estimator.htm).
- AirTest offers a spreadsheet-based demand-controlled ventilation savings analyzer (https://www.airtesttechnologies.com/support/software/index.html).

school, and an office—in each of two cities in California and three cities outside the state. Total energy savings ranged from 6.4 to over 50 percent, and payback periods ranged from 0.25 to 6.8 years, though paybacks were well under two years for most of the modeled facilities.

Keep in mind that CO_2 concentration rates do not indicate the levels of other potential air contaminants contained within the space. If a facility contains significant nonhuman sources of contaminants (such as materials or products containing volatile organic compounds), additional ventilation may be required to provide acceptable indoor air quality. This makes warehouses, kitchens, dry cleaners, and many types of industrial facilities poor candidates for DCV. Consult local building codes for proper ventilation rates.

Pick Premium-Efficiency Motors

All new motors installed in HVAC applications have been required to meet minimum federal energy-efficiency standards since October 1997. The motors that drive older HVAC systems are likely to be inefficient by today's standards, and even newer systems that meet the current federal motor efficiency standards can be made more efficient. Motors that perform to the National Electrical Manufacturers Association's NEMA Premium (NP) specification (see **Table 8.3**) can yield highly cost-effective energy savings in HVAC applications because these applications tend to have long running hours.

Table 8.3: Premium versus standard efficiencies of totally enclosed, fan-cooled motors

NEMA Premium motors often exceed the efficiencies of standard-efficiency motors by 1.5 to 2 percent. Although that may not seem like much, given their very long running hours in HVAC applications, it is often quite easy to justify the higher cost of premium-efficiency motors based on energy savings alone, particularly if the local utility offers a rebate.

	Efficiency (%)					
	3,600 rpm		1,800 rpm		1,200 rpm	
Motor horsepower	Standard	NEMA Premium	Standard	NEMA Premium	Standard	NEMA Premium
1.0	75.5	77.0	82.5	85.5	80.0	82.5
1.5	82.5	84.0	84.0	86.5	85.5	87.5
2.0	84.0	85.5	84.0	86.5	86.5	88.5
3.0	85.5	86.5	87.5	89.5	87.5	89.5
5.0	87.5	88.5	87.5	89.5	87.5	89.5
7.5	88.5	89.5	89.5	91.7	89.5	91.0
10.0	89.5	90.2	89.5	91.7	89.5	91.0
15.0	90.2	91.0	91.0	92.4	90.2	91.7
20.0	90.2	91.0	91.0	93.0	90.2	91.7
25.0	91.0	91.7	92.4	93.6	91.7	93.0
30.0	91.0	91.7	92.4	93.6	91.7	93.0
40.0	91.7	92.4	93.0	94.1	93.0	94.1
50.0	92.4	93.0	93.0	94.5	93.0	94.1
60.0	93.0	93.6	93.6	95.0	93.6	94.5
75.0	93.0	93.6	94.1	95.4	93.6	94.5
100.0	93.6	94.1	94.5	95.4	94.1	95.0

Courtesy: E SOURCE; data from NEMA and U.S. Department of Energy

After completing the building upgrade stages described earlier in this manual, building heating and cooling loads are likely to have been reduced, allowing for the installation of smaller motors that better match the reduced power requirements. Although NP motors also often come with a price premium, the cost of a smaller, premium-efficiency motor will often be less than that of a standard-efficiency motor of the same size as the existing motor, making the premium-efficiency motor an easy choice. Also, many utilities offer rebates on the purchase of NP motors that are designed to cover all or a portion of the price premium.

The DOE offers a free software application called MotorMaster that is an excellent tool for evaluating the economics of alternative motor choices. The software comes with a frequently updated database of commercially available motors and allows the user to compare the initial and lifecycle cost implications of replacing an existing motor with a standard- or premium-efficiency motor. MotorMaster can be downloaded from www1.eere.energy.gov/industry/bestpractices/software.html#mm.

Here are a few additional issues to consider when evaluating HVAC motors.

Motor speed. Some premium-efficiency motors operate at higher speeds. All induction motors have a synchronous speed (the speed at which the magnetic field within the motor is rotating) and a full-load speed (the speed at which the motor shaft rotates when the motor is providing full-load torque or power). A motor's full-load speed will always be less than its synchronous speed by a few percent. The difference between synchronous and full-load speed is called slip.

The exact amount of slip a motor has depends on its design, construction, and loading. Be aware that premium-efficiency motors tend to have lower slip, which means that their full-load speed tends to be higher than that of less-efficient models. As noted earlier, the power a fan requires to move air varies by the cube of its speed, so power draw and energy consumption are very sensitive to motor speed. In air-circulation systems that are not controlled by a VSD, it is therefore conceivable that replacing an existing motor with a NP motor could actually result in greater energy consumption, even though the new motor operates at higher efficiency. Therefore, when selecting a premium-efficiency motor, it is important to compare its rated full-load speed to that of the motor it will replace. If necessary, the fan's speed can be reduced by increasing the diameter of its pulley.

Voltage balance. Three-phase induction motors (that is, motors that draw power from three phase conductors) are designed, specified, and rated by their manufacturers on the assumption that exactly the same voltage will be fed to each phase and that equal current will therefore flow through the coils connected to each phase, generating a uniform magnetic field from each pole pair. When this voltage is not balanced, however, significant harm can come to the motor, including reduced performance, increased heat, shortened life, and dramatically reduced efficiency. Phase unbalance dramatically increases the heat generated within a motor. That increase then feeds upon itself, because hotter windings have higher resistance, pushing up losses further. Just a 3.5 percent unbalance can increase total motor losses by 20 to 25 percent, which is equivalent to bringing the efficiency of a 90 percent efficient motor down to 87.5 to 88 percent.

Unbalance is defined by NEMA as 100 times the maximum deviation from the average of the voltages on the three phases, divided by that average voltage. For example, if the phase voltages measured at a motor's terminals are 465, 470, and 473 volts, the average voltage is 469.3 and

the maximum deviation is 4.3 volts. The unbalance, then, is 4.3/469.3 = 0.9 percent. A well-balanced system should have voltage unbalance of less than 1 percent. If voltage unbalance is greater than 1 percent, evaluate the loading on each phase. The unbalanced phase may be carrying significantly more or less load than the others, in which case rebalancing the loads across the phases will also rebalance phase voltages.

Shaft alignment. In typical fan-system configurations, the motor and the fan each have shafts that are connected with a belt or belts and two pulleys. If the pulley faces are not square with each other, then the belt and shafts are not in alignment. Improperly aligned shafts can not only result in poor efficiency and higher operating costs, but also can lead to premature failure and increased maintenance costs. Whenever a motor is replaced or rewound, be sure to pay close attention to the shaft alignment.

Use Energy-Efficient Belt Drives

Belts are often used to transfer power from the motor to the fan system being driven. Standard V-belt drives can be found in the majority of belt applications. They are the lowest-cost option of the belt family. The trade-off, as usual, is reduced energy efficiency. New V-belts typically achieve efficiencies in the 90 to 95 percent range. A worn belt, however, can considerably reduce the efficiency by slippage caused by slackening and worn grip surfaces. Cogged V-belts are similar to standard V-belts, except that the normally flat underside has longitudinal grooves in it, allowing better grip and less slip than standard V-belts. They typically offer a 2 to 5 percent efficiency bonus.

Less commonly found synchronous belts combine toothed belts with grooved sprockets. The belts are called "synchronous" because both sprockets rotate in exact synchrony, eliminating losses from slippage and creep and significantly reducing maintenance because the nonstretch belt does not need retensioning. These belts transmit power by engaging teeth rather than tension-induced friction, so they operate much more efficiently than V-belts, achieving efficiencies in the range of 97 percent to 99 percent.

A potential downside to synchronous belts is that by reducing slippage, they will actually increase the speed of the fan, which will result in more airflow, but it will also require more power from the motor. For example, reducing belt slip on a constant-volume centrifugal fan by 3 percent will result in a corresponding 3 percent increase in rotational speed for the fan wheel and an increase in the volume of air that is delivered. Because such a fan has a cubic relationship between airflow and horsepower, however, the horsepower required to drive the fan will increase by $(1.03)^3$, or 1.093—a 9.3 percent increase from the previous requirements. So the building owner who wants energy savings may instead be getting increased airflow and increased energy use (and possibly an overheated fan motor) if the proper precautions are not taken. Retrofits from V-belts to synchronous belts should be coordinated with the replacement of standard-efficiency motors with properly sized premium-efficiency motors. Doing both retrofits together reduces total labor costs and offers an opportunity to correct for any changes in speed from the new motor or belts at zero marginal cost. Additionally, when selecting synchronous belts it is important to follow manufacturer guidelines for sizing and tensioning the belts to ensure quiet, trouble-free operation.

V-belts should be a standard replacement part in every building's maintenance program, requiring replacement every few months. Energy-efficient synchronous belts can easily be incorporated into a standard maintenance program, and the savings generated greatly outweigh the slight increase in cost per belt.

Consider a Testing, Adjusting, and Balancing Contractor

The modifications outlined above are likely to alter the operating characteristics of a building's HVAC system. Normally, the engineer or contractor who performed the work will be responsible for what is called the testing, adjusting, and balancing (TAB) of the modified or new system. TAB involves measuring and analyzing the various flows of air, chilled water, hot water, steam, etc., and ensuring that distribution of heating and cooling throughout the building meets the required specifications as outlined in the contract documents. Independent TAB contractors serve as an unbiased third party to ensure accuracy of the TAB measurements and are worth retaining if further oversight is desired. To find a qualified TAB firm, look for a firm that is certified by a recognized national professional society such as the Associated Air Balance Council. In addition, confirm that the TAB firm has experience with balancing systems in the type of facility in question (such as office, university building, or laboratory). Finally, ask for references.

8.5 Summary

This chapter illustrates the many options that are available to optimize constant-volume and variable air volume air distribution systems. Some of the strategies to remember are:

- Address zone-level opportunities first.
- Consider converting a CV system to VAV.
- Rightsize fan system to match actual loads.
- Install VSDs where practical.
- Consider improved controls to optimize scheduling and to implement temperature or pressure reset, economizer cooling, and demand-controlled ventilation.
- Install rightsized, premium-efficiency motors where possible.
- Install energy-efficient belts.

Bibliography

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), "Energy Standard for Buildings Except Low-Rise Residential Buildings," ANSI/ASHRAE/IESNA Standard 90.1-2004, www.ashrae.org.

ASHRAE, "Ventilation for Acceptable Indoor Air Quality," ASHRAE Standard 62.1-2004, www.ashrae.org.

California Energy Commission, "Advanced Variable Air Volume System Design Guide" (October 2003), http://energy.ca.gov/reports/2003-11-17_500-03-082_A-11.PDF.

California Energy Commission, *Guide to Preparing Feasibility Studies for Energy-Efficiency Projects*, P400-00-002 (California Energy Commission, 2000).

Englander, S.L. and L.K. Norford, "Saving Fan Energy in VAV Systems, Part 1: Analysis of a Variable Speed Retrofit," ASHRAE Transactions 1992a: 98.

NEMA, "Application Guide for AC Adjustable Speed Drive Systems" (2007), www.nema.org/stds/acadjustable.cfm.

U.S. Department of Energy, Energy Information Administration, "End-Use Consumption by Principal Building Activity" (1999), www.eia.doe.gov/emeu/cbecs/enduse_consumption/pba.html.

Energy Savings Report

ECM # 6 Facility Envelope Improvement

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	Exterior windows
Product or Process:	Sealing of window drafts
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Brian Peifer, CEM

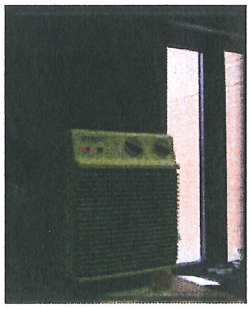
Tozour Energy Services
THE POWER TO SAVE

Project Scope Definition

Project consists of caulking & resealing windows, gaskets replaced as needed.

Facility employees indicated they feel drafts of cold air from the windows during the Winter season. In some areas the drafts were visible as paper moved on desk adjacent to windows. Some walls below windows showed stains from water that has leaked into the building over the years. There are radiant heating panels mounted in the ceiling above most of the windows but the panels have little affect in overcoming the cold air leakage. Our recommendation is to inspect and seal all windows. This improvement will have small energy savings benefits in both the heating and cooling seasons by reducing the transfer of heat in or out of the building. Comfort will be improved.

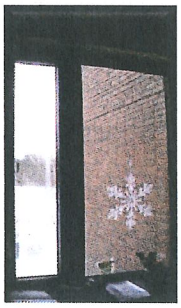
Existing Conditions & Planned Improvements



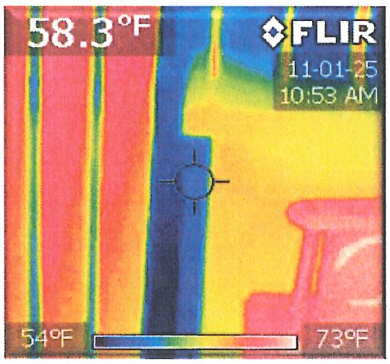
Space heaters used due to drafts



Existing radiant heat panel



Window condensation



Infrared shows cold temperature at window pane

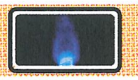
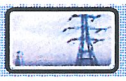
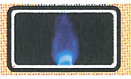
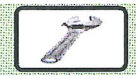
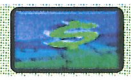
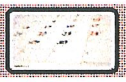
Energy Savings Report

ECM # 6 Facility Envelope Improvement

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	Exterior windows
Product or Process:	Sealing of window drafts
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Brian Peifer, CEM

Tozour Energy Services
THE POWER TO SAVE

Cost & Savings Analysis - Savings calculated by the Trace 700 building model simulation program

	Installation Cost	$17,500	
	Reduction in Electric Consumption	226	kWh
	Reduction in Electric Demand	3	kW
	Reduction in Natural Gas	63	dTh
	Electrical Consumption Cost	$0.1645	/ kWh
	Electrical Demand Cost	$0.00	/ kW
	Natural Gas Cost	$12.29	/ dTh
	Annual Energy Savings	$814	
	Annual Operational Savings	$0	
	Annual Total Savings	$814	
	Pay for Performance Incentive	$0	
	Simple Payback - No Incentive	21.5	Years
	Simple Payback with P4P Incentive	N/A	Years
	Reduction in CO_2	3	Tons
	Equivalent Additional Trees	17	Trees
	Equivalent Reduction in Automobiles	1	Cars

Energy Savings Report

ECM # 7 VAV Box Replacement

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	All office area excluding court room
Product or Process:	Replace VAV boxes above ceiling
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Michael Phillips, Project Manager

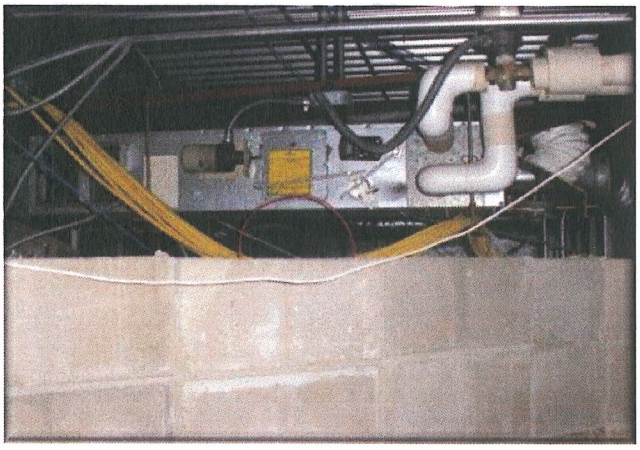
Tozour Energy Services
THE POWER TO SAVE

Project Scope Definition

Full replacement of 57 VAV boxes above the ceiling, includes electrical piping, and sheet metal

VAV boxes in the building are original and there have been various problems with the operation of them. The controls upgrade (ECM-4) deals with several of those issues and the bulk of the energy savings as the replacement of hot water valves, damper actuator, and thermostats are included. If financially viable under the ESIP program this ECM would allow entirely new VAV boxes to be installed which would slightly further improve the energy efficiency and comfort level of the office areas. An economy of scale would be realized with this project being done in conjunction with the VAV box controls upgrade. Savings for this ECM appear small with a very long payback but it must be realized that nearly all the VAV box savings will come from a properly functioning control system programmed to optimize efficiency.

Existing Conditions



Existing VAV box above 2nd floor hallway

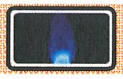
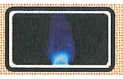
Energy Savings Report

ECM # 7 VAV Box Replacement

Date Submitted:	March 4, 2011
Project:	Manalapan Main Township Building & Police Headquarters
Building or Area	All office area excluding court room
Product or Process:	Replace VAV boxes above ceiling
Investigator:	Brian Peifer, CEM
Reviewed By:	Raymond Johnson PE
Estimator:	Michael Phillips, Project Manager

Tozour Energy Services
THE POWER TO SAVE

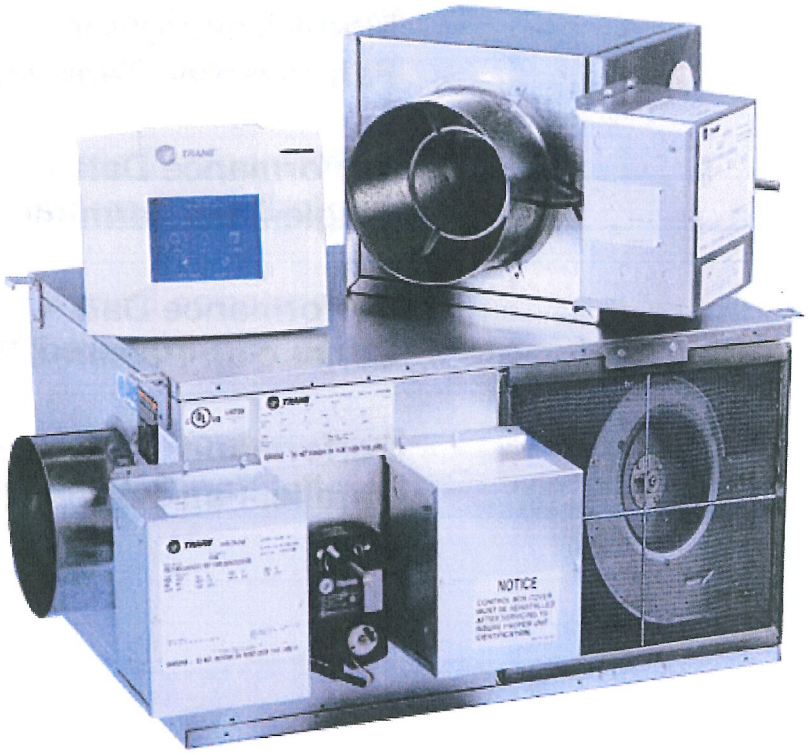
Cost & Savings Analysis - Savings calculated by the Trace 700 building model simulation program

	Installation Cost	$170,550	
	Reduction in Electric Consumption	1,242	kWh
	Reduction in Electric Demand	1	kW
	Reduction in Natural Gas	7	dTh
	Electrical Consumption Cost	$0.1645	/ kWh
	Electrical Demand Cost	$0.00	/ kW
	Natural Gas Cost	$12.29	/ dTh
	Annual Energy Savings	$289	
	Annual Operational Savings	$0	
	Annual Total Savings	$289	
	Pay for Performance Incentive	$0	
	Simple Payback - No Incentive	590.0	Years
	Simple Payback with P4P Incentive	N/A	Years
	Reduction in CO_2	1	Tons
	Equivalent Additional Trees	6	Trees
	Equivalent Reduction in Automobiles	0	Cars

TRANE

VariTrane VAV Terminal Unit

Single-Duct
Series Fan-Powered
Parallel Fan-Powered



TRANE

Contents

VAV System Overview 3

VariTrane VAV Terminal Unit Overview 5

Model Description – Single-Duct Terminal Units 8

Model Description – Fan-Powered Terminal Units 9

Performance Data – Single-Duct Terminal Units 10

Performance Data – Series Fan-Powered Terminal Units 15

Performance Data – Parallel Fan-Powered Terminal Units 22

VAV System Overview

System Introduction

In a Variable Air Volume (VAV) system, air delivery volume varies directly with the changing cooling or heating load, thus saving energy at part load conditions. Another benefit that makes VAV a popular choice in HVAC design is its capability to control temperature in multiple zones. Compared to conventional constant volume system, VAV system has multiple VAV terminal boxes each serving a zone controlling air flow to that zone and maintaining the set-point temperature.

Trane leads in VAV technology with its innovative range of VariTrane units (Single-duct and Fan-powered types) that are designed for diverse applications and environments. Applications include office space, hospitals, hotels, retail stores, malls and educational facilities. VariTrane provides the most reliable and flexible products available, further enhanced by Trane DDC controls in implementing systems-level control strategies like ventilation reset and Static Pressure Optimization to improve systems performance and efficiency.

VAV System Features and Benefits

VAV systems have the following features and benefits:

1. Economical Operation

VAV systems can change the supply air volume according to the cooling and heating load variation to enable the cooling, heating capacity and fan power to meet actual load requirement. Therefore, the system energy consumption can be significantly reduced. Meanwhile, if compared with traditional air conditioning systems, VAV systems can utilize the outdoor fresh air as much as possible during transitional seasons, which not only saves energy consumption, but also improves indoor air quality. It is estimated that over 30% of the annual energy consumption can be saved and 10-30% of total equipment capacity can be reduced by using VAV system.

2. Improved Indoor Air Quality and Comfort

With the integrated DDC control, VariTrane VAV terminal units can keep room temperature and air volume within the pre-set range per actual cooling or heating load requirement and enhance control accuracy of the terminal unit. It allows room temperature to be adjusted per application requirement. Supply air of VAV system can be remote and centralized controlled to improve the system efficiency and room air quality.

3. Reliable Operation, Simple Construction

VAV system is an all-air system. There is no water piping passing through the ceiling of the room, which can avoid problems such as condensation, water leakage and bacteria breeding which may happen in the fan coil system. In addition, VariTrane VAV boxes have simple casing construction, which makes installation simple and easy.

4. Flexible System

Renovation always occurs in modern buildings. By using flexible duct connection, modification of VariTrane VAV terminal unit position can be done according to the room partition and requirement with minimum field modification cost, labor and time.

5. Compatible System

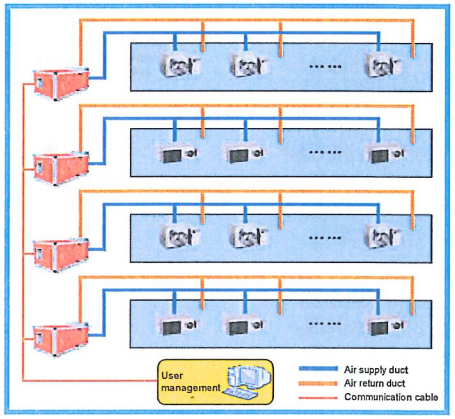
VAV systems can be integrated with other air conditioning systems to optimize performance efficiency. For example, when integrated with ice storage system, the application of cold air distribution can reduce the initial investment of ice storage system effectively; when integrated with heat pump system it can reduce the initial investment, reducing the noise level by installing several water heat pumps in central location and avoid costly installation of heat pump at each floor.

6. Easy to get integrated with Building Automation (BA) system

VAV systems can be integrated to BA system via DDC control. System optimization and monitoring of the whole system can be achieved by computerized control.

VAV System Structure

A typical VAV System consists of:
1.Air handling units
2.Air duct system
3.VariTrane VAV terminal nuit



VAV System Schematic

VAV System Overview

System Control Introduction

The VariTrane VAV box can be connected to Trane's Building Automation System through two types of control systems.

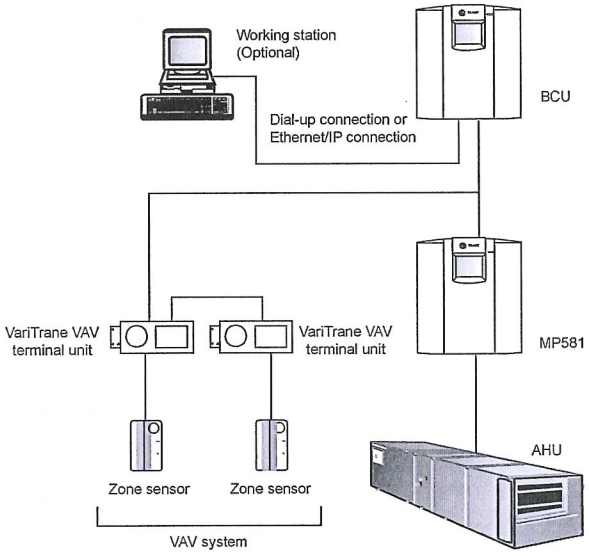
Tracer System

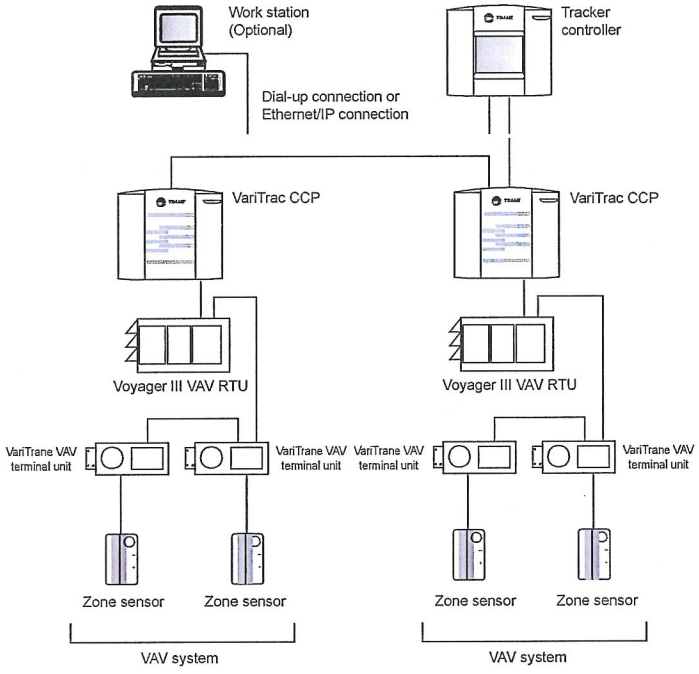
In Tracer, the work station using Tracer Summit software monitors the whole system and has many functions such as operating parameter setting, data acquisition, alarming, reports, clock, etc. The Building control Unit (BCU) provides control logic for the whole system and coordinates the operation between equipment level controllers such as MP581 and VAV controllers. VAV controllers are connected to each other by using RS485, and then connected to BCU. The whole control system structure is simple, compatible and designed to accommodate future extension requirements.

In addition, using LonTalk DDC controllers, VariTrane VAV terminal units can be connected to third party control systems which have LonTalk protocol.

Tracker system

In Tracker, the work station is connected to a Tracker controller. It acquires equipment status, system data information, control command and monitors the system equipment. The Tracker controller provides control logic for the whole system. It coordinates the rooftop equipment (Voyager) & VariTrane VAV terminal unit control through the CCP (central control panel). One Tracker controller can be connected to several CCPs, and each CCP is connected to one rooftop unit (Voyager) and several VariTrane VAV boxes. Inter communication is possible between CCPs. All equipment connections in the system are PnP (plug and play), making it convenient for installation and application.





VariTrane VAV Terminal Unit Overview

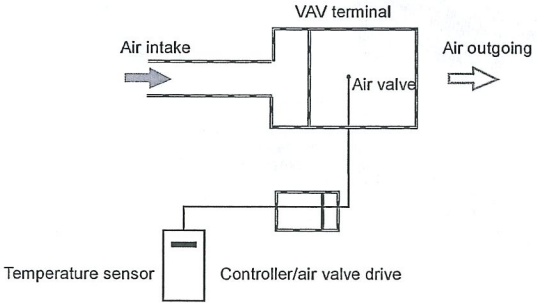
VAV Terminal Unit Classification

A VAV terminal unit controls the air valve opening and regulates the air volume in the room by measuring the temperature difference between room and set point. There are two basic working principles of a VAV box: pressure-dependent and pressure-independent.

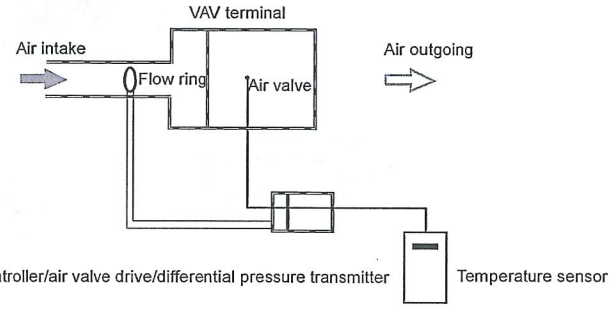
A pressure-dependent VAV control scheme uses the space temperature sensor to control the position of the modulating device directly. The actual airflow delivered to the space depends on the duct system static pressure at the inlet of the terminal unit. Although the space temperature sensor will continually correct the position of the modulating device, the response can be sluggish and cause unacceptable temperature variations within the space.

In contrast, a pressure-independent VAV control scheme controls the actual volume of primary air that flows to the space. An airflow-measuring device on the terminal unit makes it possible. The position of the modulation device is not directly controlled and is basically a by-product of regulating the airflow through the unit. Because the airflow delivered to the space is directly controlled, it is independent of inlet static pressure.

Pressure-independent control increases the stability of airflow control and allows minimum and maximum airflow settings to become actual airflows rather than physical positions of the modulation device. It is clearly most popular in all VAV terminal unit controls.

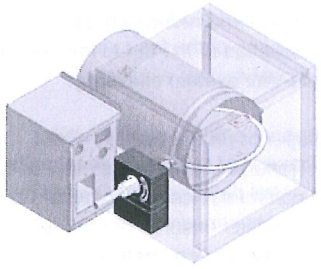


Pressure-dependent

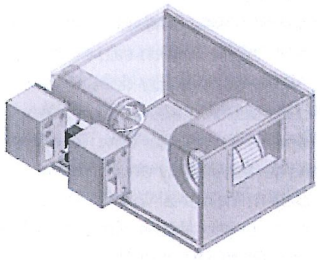


Pressure-independent

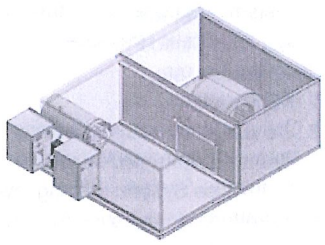
There are three basic types of VariTrane VAV terminal units, Single-duct (without fan), Series Fan-Powered and Parallel Fan-Powered.



Single-duct



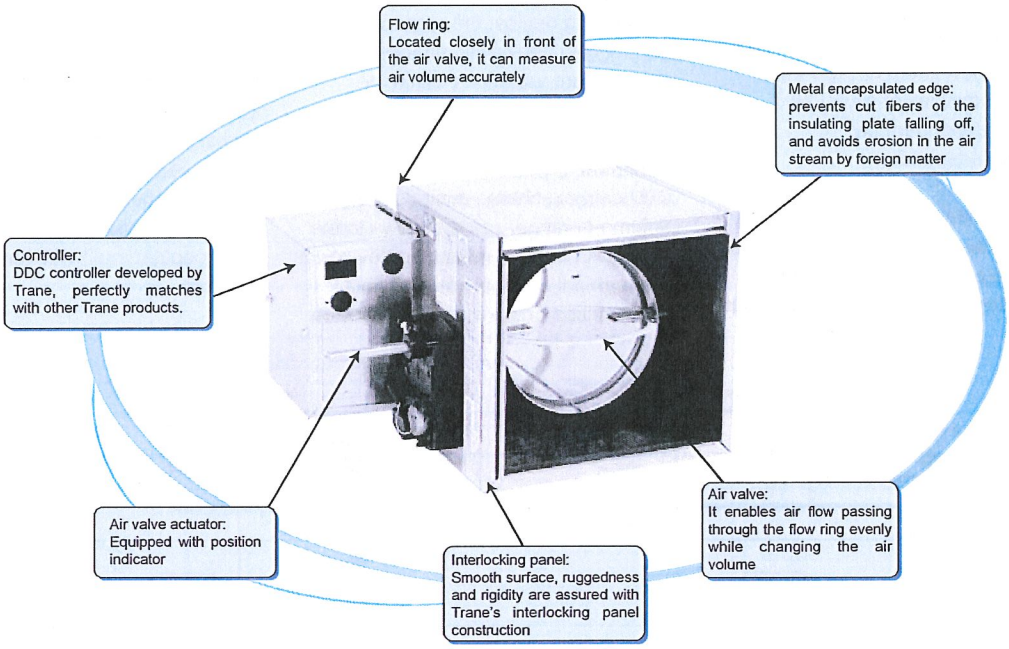
Series fan-powered



Parallel fan-powered

VariTrane VAV Terminal Unit Overview

Features and Benefits



Energy Efficiency

VAV systems can save energy significantly, comply with ventilation requirements, and provide reliable and personalized occupant control.

Energy saving features of VariTrane VAV terminal units include:

1. System strategies like Ventilation Reset, and Static Pressure Optimization, etc
2. Night setback
3. Occupied/unoccupied control
4. Demand controlled ventilation
5. EarthWise System utilizing low temperature air and system energy optimization.

Advanced Control

With years of working experience and understanding of VAV system characteristic, Trane has developed a reliable DDC controller for VAV system which has unique functions:

1. Advanced system integration–VariTrane VAV terminal unit DDC controller uses pressure-independent control mode, which can obtain precise air valve opening by doing two-time PID calculation according to the temperature and air flow to control air volume accurately and provide excellent indoor air quality and comfort control. It can also be integrated with Trane Tracer Summit Building Automation System. It is the most advanced VAV control system in the field. This system has a series of unique control modes such as fresh air volume / ventilation reset, static pressure optimization control which can meet the current industry regulations and standards, able to adjust air duct static pressure effectively and reduce energy consumption of the fan to improve the whole VAV system efficiency.

2. Superior product quality–Both VariTrane VAV system terminal units and control devices are provided by Trane, which ensures the product quality, system compatibility and perfect system integration.

VAV Terminal Unit Overview

Controls Parts and Options

UCM4 is a microprocessor-based DDC controller using pressure-independent control mode to control the supply air volume accurately to make room temperature reach the set condition. In addition, UCM4 also has additional functions, such as optional CO_2 sensor, wireless sensor, to fulfill various customer and application requirements.



UCM4

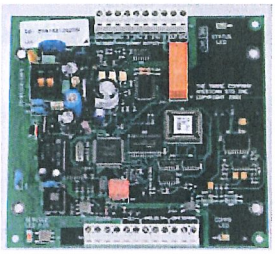
CO_2 sensor is used to measure CO_2 concentration in the air, converts it into electrical signal and then transmit the signal to the controller which will reset fresh air volume accordingly to ensure indoor air quality and comfort.

Wall mounted



Duct mounted

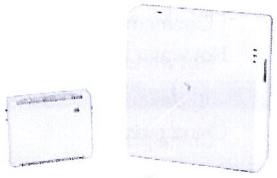
VV550/551 is a LonTalk protocol-based DDC controller which can provide precise control to VariTrane VAV terminal unit. It also has good universality and compatibility, especially in connecting to the third party Building Automation System with LonTalk protocol.



VV550/551

Auxiliary temperature sensor helps VariTrane VAV terminal unit changeover between heating and cooling mode automatically without the system controller. Terminal unit controller will compare the temperature differences between the supply air temperature provided by auxiliary temperature sensor and the room temperature provided by zone sensor. It will determine the working mode automatically according to the result without manual adjustment.

Wireless sensor eliminates the wiring difficulty at the field and provides more flexibility for layout and sensor positioning. Trane wireless sensor is based on wide spectrum technology, This enhances system security greatly and avoids interference problem when using different system with the same frequency in the same area.



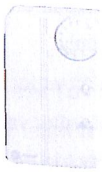
Wireless sensor



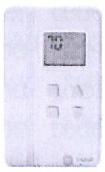
Auxiliary temperature sensor

Area sensor

Model	Zone sensor		Occupied / Unoccupied Mode		LCD
	Temperature setting	Internal sensor	ON	CANCEL	
4190 1090	√	√	√	√	
4190 1120	√	√	√	√	√



4190 1090



4190 1120

VariTrane Model Description Single-Duct

V	C	C	T	0	6	0	0	A	0	D	D	0	1	D	0	0	0	0	L	0	0	0	0	0	0	0	0	0	0
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

Digit 1~2— Unit Type

VC	Single duct

Digit 3— Terminal Heating Mode

C	None
E	Electric heating
W	Hot water heating

Digit 4— Development Series No.

T	China plant

Digit 5~6— Dimension of Primary Air Valve Inlet

05	5"
06	6"
08	8"
10	10"
12	12"
14	14"
16	16"

Digit 7~8— Reserved

00	N/A

Digit 9 —Reserved

0	N/A

Digit 10~11— Design No.

A0	Initial development

Digit 12~15— Control Mode

DD00	Trane elec actuator only
DD01	DDC cooling only
DD02	DDC N.C. on/off water valve
DD03	DDC prop hot water valve
DD04	DDC on/off electric heat control
DD11	LonTalk DDC cooling only
DD12	LonTalk DDC N.C. on/off water valve
DD13	LonTalk DDC prop hot water valve
DD14	LonTalk DDC on/off electric heat control
FM00	Customers supply the air valve actuator and controller by themselves

Digit 16 —— Insulation

B	1" Matte-faced
D	1" foil faced
F	1" Double-wall
G	3/4" Closed-cell

Digit 17— Reserved

0	N/A

Digit 18— Reserved

0	N/A

Digit 19—Reserved

0	N/A

Digit 20— Reserved

0	N/A

Digit 21— Hot Water Coil

0	N/A
1	1 row
2	2 rows

Digit 22—Electric Connection

L	Left type

Digit 23— Transformer

0	N/A
1	115VAC/24V AC transformer
3	230VAC/24V AC transformer

Digit 24— Power Disconnect

0	N/A
W	With

Digit 25— Power Fuse

0	N/A
W	With

Digit 26— Electric Heating Voltage

0	N/A
C	Single-phase 220V
J	Three-phase 380V

Digit 27~29— Electric Heating Power

000	N/A
010	1.0kW
020	2.0kW
300	30kW

Note: For detailed specification, refer to the electric heater information

Digit 30— Electric Heat Stage

0	N/A
1	1 stage
2	2 stages
3	3 stages

Digit 31— Reserved

0	N/A

Digit 32— Reserved

0	N/A

VariTrane Model Description Fan-Powered

V	S	C	T	0	6	0	0	P	A	0	D	D	0	1	D	D	5	2	0	0	L	0	0	0	0	0	0	0	0	0	0
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

Digit 1~2— Unit Type

VP	Parallel fan-powered
VS	Series fan-powered

Digit 3— Terminal Heating Mode

C	None
E	Electric heating
W	Hot water heating

Digit 4—Development Series No

T	China plant

Digit 5~6— Primary Air Valve

05	5"
06	6"
08	8"
10	10"
12	12"
14	14"
16	16"

Digit 7~8— Reserved

00	N/A

Digit 9— Fan model

P	02SQ
Q	03SQ
R	04SQ
S	05SQ
T	06SQ
U	07SQ

Digit 10~11— Design No.

A0	Initial development

Digit 12~15— Control Mode

DD00	Trane elec actuator only
DD01	DDC cooling only
DD02	DDC N.C. on/off water valve
DD03	DDC prop hot water valve
DD04	DDC on/off electric heat control
DD11	LonTalk DDC cooling only
DD12	LonTalk DDC N.C. on/off water valve
DD13	LonTalk DDC prop hot water valve
DD14	LonTalk DDC on/off electric heat control
FM00	Customers supply the air valve actuator and controller by themselves

Digit 16— Thermal Insulation

B	1" Matte-faced
D	1" foil faced
F	1" Double-wall
G	3/4" Closed-cell

Digit 17— Motor Type

D	Standard motor

Digit 18— Motor Voltage

1	115V/60Hz/1P
4	230V/60Hz/1P
5	230V/50Hz/1P

Digit 19— Outlet Connection

1	Flange connection
2	Slip & Drive

Digit 20— Attenuator

0	N/A
W	With

Digit 21— Hot Water Coil

0	N/A
1	1 row – inlet (only for parallel fan-powered)
2	2 rows – inlet (only for parallel fan-powered)
3	1 row —Outlet—Left
5	2 rows—Outlet—Left

Digit 22—Electrical Connections

L	left

Digit 23— Reserved

0	N/A

Digit 24— Power Disconnect

0	N/A
W	with

Digit 25— Power Fuse

0	N/A
W	with

Digit 26— Electric Heating Voltage

0	N/A
C	Single-phase 220V
J	Three-phase 380V

Digit 27~29— Electric Heating Power

000	N/A
010	1.0kW
020	2.0kW
~	~
200	20kW

Note: For detailed specification, refer to the electric heater information

Digit 30—Electric Heat Stage

0	N/A
1	1 stage
2	2 stages
3	3 stages

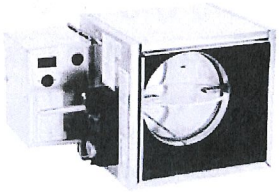
Digit 31— Reserved

0	N/A

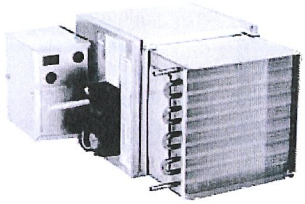
Digit 32— Airflow Switch

0	N/A
W	With

Performance Data
VariTrane Single-Duct



VCCT single-duct terminal device (cooling only)



VCWT heating-water heating terminal device



VCET electric heating terminal device

Performance Data

Air valve	Inlet diameter mm	Airflow range m^3/h	Min. airflow m^3/h	Dimension mm(L × W × H)	Weight (kg)
05	127	68-595	68	443×433×241	9.5
06	152	101-850	101	411×433×241	9.5
08	203	180-1530	180	398×458×292	10
10	254	277-2380	277	424×534×343	14
12	305	400-3400	400	449×610×394	17
14	356	544-5100	544	475×661×495	21
16	406	713-6800	713	500×763×495	23

Air Pressure Drop (Pa)

Single-duct VAV terminal device					
Air valve	Airflow (m^3/h)	Casing	Heating coil		Electric heater
			1 row	2 row	
05	162	3	5	8	5
	342	3	9	18	8
	504	3	19	38	10
	595	4	25	50	15
06	162	3	5	8	5
	432	13	16	30	8
	594	26	29	53	10
	850	55	57	100	15
08	342	3	5	10	5
	684	4	21	39	10
	1008	9	40	74	15
	1530	21	78	148	15
10	846	3	13	26	10
	1350	3	34	60	15
	1872	3	64	107	20
	2380	3	101	162	20
12	1350	3	21	44	10
	2034	3	44	85	20
	2718	3	73	135	20
	3400	3	108	192	25
14	2520	3	23	52	15
	3402	3	37	86	20
	4248	3	53	124	20
	5100	3	71	168	25
16	3384	3	25	70	20
	4248	3	37	111	20
	5094	3	51	159	25
	6800	3	84	281	25

Note: The air pressure drops in the table refer to the pressure drops of the parts.

Performance Data
VariTrane Single-Duct

Heating Capacity of Hot Water Coil (kW)

Air Valve	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m^3/h)									
				76	102	153	170	255	340	425	595	680	850
05/ 06	1 Row	0.03	1.57	1.20	1.38	1.66	1.73	2.05	2.30	2.52	2.86	3.01	3.26
		0.06	5.26	1.27	1.49	1.82	1.91	2.31	2.64	2.93	3.41	3.63	4.01
		0.09	10.72	1.30	1.53	1.88	1.98	2.42	2.78	3.10	3.65	3.91	4.35
		0.13	17.82	1.32	1.55	1.91	2.02	2.47	2.86	3.20	3.78	4.06	4.54
		0.16	26.47	1.32	1.56	1.93	2.04	2.51	2.91	3.26	3.87	4.16	4.67
	2 Row	0.06	1.85	1.48	1.88	2.54	2.73	3.53	4.14	4.61	5.29	5.58	6.00
		0.13	6.39	1.52	1.94	2.68	2.90	3.84	4.60	5.22	6.15	6.56	7.19
		0.19	13.28	1.53	1.96	2.72	2.95	3.96	4.77	5.45	6.49	6.96	7.69
		0.25	22.39	1.54	1.97	2.75	2.98	4.01	4.86	5.57	6.68	7.18	7.96
		0.32	33.61	1.54	1.98	2.76	3.00	4.05	4.92	5.65	6.80	7.32	8.14

Scope Size 05
Size 06

Air Valve	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m^3/h)								
				280	340	510	680	850	1019	1189	1359	1530
08	1 Row	0.03	2.12	2.47	2.66	3.12	3.47	3.75	3.99	4.18	4.35	4.50
		0.06	7.05	2.81	3.06	3.68	4.18	4.61	4.99	5.33	5.63	5.90
		0.09	14.35	2.94	3.22	3.92	4.49	4.99	5.44	5.84	6.22	6.56
		0.13	23.82	3.01	3.31	4.05	4.67	5.22	5.71	6.15	6.56	6.93
		0.16	35.35	3.06	3.37	4.13	4.78	5.36	5.88	6.35	6.79	7.20
	2 Row	0.13	0.98	4.40	4.97	6.25	7.18	7.88	8.44	8.89	9.26	9.58
		0.25	3.48	4.54	5.18	6.67	7.79	8.69	9.42	10.03	10.55	11.01
		0.38	7.37	4.65	5.33	6.92	8.16	9.16	9.99	10.70	11.30	11.83
		0.50	12.56	4.70	5.40	7.06	8.36	9.42	10.31	11.07	11.72	12.29
		0.63	19.04	4.74	5.45	7.15	8.49	9.59	10.51	11.30	11.99	12.59
		0.79	28.90	4.77	5.49	7.22	8.60	9.73	10.68	11.50	12.22	12.84

Air Valve	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m^3/h)									
				595	765	934	1104	1274	1444	1699	1869	2209	2380
10	1 Row	0.04	5.29	4.36	4.83	5.21	5.54	5.83	6.08	6.41	6.61	6.94	7.09
		0.06	9.81	4.74	5.27	5.75	6.17	6.54	6.88	7.33	7.60	8.07	8.28
		0.09	19.90	5.09	5.71	6.26	6.75	7.21	7.63	8.21	8.55	9.18	9.47
		0.13	33.00	5.28	5.96	6.56	7.10	7.60	8.07	8.71	9.11	9.84	10.17
		0.16	48.93	5.40	6.11	6.75	7.33	7.87	8.37	9.06	9.48	10.28	10.64
	2 Row	0.13	2.07	7.87	8.98	9.87	10.59	11.20	11.72	12.36	12.73	13.34	13.60
		0.25	7.53	8.64	10.06	11.23	12.23	13.10	13.85	14.81	15.37	16.34	16.75
		0.38	16.15	8.93	10.46	11.76	12.88	13.86	14.72	15.83	16.49	17.62	18.12
		0.50	27.83	9.07	10.68	12.05	13.23	14.27	15.19	16.40	17.10	18.34	18.88
		0.63	42.50	9.17	10.81	12.22	13.45	14.53	15.49	16.75	17.50	18.80	19.38

Air Valve	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m^3/h)								
				680	1019	1359	1699	2039	2379	2718	3058	3400
12	1 Row	0.06	2.04	5.30	6.19	6.88	7.44	7.90	8.29	8.64	8.93	9.20
		0.13	7.08	6.08	7.28	8.25	9.10	9.85	10.51	11.11	11.65	12.14
		0.19	14.79	6.40	7.74	8.86	9.84	10.71	11.50	12.23	12.90	13.52
		0.25	25.04	6.57	8.00	9.20	10.26	11.22	12.09	12.89	13.63	14.33
		0.32	37.73	6.68	8.16	9.42	10.54	11.55	12.48	13.33	14.13	14.87
	2 Row	0.13	0.74	9.27	11.32	12.71	13.71	14.47	15.07	15.56	15.97	16.30
		0.32	4.12	10.42	13.37	15.59	17.33	18.74	19.92	20.91	21.77	22.51
		0.50	10.01	10.82	14.09	16.63	18.68	20.37	21.80	23.03	24.10	25.04
		0.69	18.35	11.01	14.44	17.15	19.35	21.20	22.77	24.13	25.32	26.38
		0.88	29.06	11.12	14.65	17.46	19.77	21.71	23.37	24.81	26.08	27.21
		1.10	44.53	11.21	14.81	17.70	20.08	22.10	23.83	25.34	26.67	27.86

Performance Data
VariTrane Single-Duct

Air Valve	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m^3/h)									
				1189	1529	1869	2209	2549	2888	3398	3908	4417	5100
14	1 Row	0.13	3.69	9.31	10.31	11.21	11.99	12.68	13.30	14.12	14.84	15.47	16.20
		0.19	7.67	10.07	11.26	12.31	13.24	14.11	14.91	15.98	16.94	17.80	18.82
		0.25	12.93	10.49	11.80	12.97	14.01	14.97	15.86	17.08	18.20	19.21	20.43
		0.32	19.43	10.76	12.15	13.39	14.52	15.55	16.51	17.83	19.04	20.16	21.52
		0.38	27.13	10.95	12.40	13.69	14.88	15.97	16.98	18.39	19.67	20.85	22.31
		0.44	36.01	11.09	12.58	13.92	15.14	16.28	17.33	18.80	20.15	21.40	22.92
	2 Row	0.32	3.24	16.31	18.74	20.71	22.34	23.71	24.89	26.38	27.62	28.66	29.83
		0.57	9.93	17.50	20.41	22.85	24.92	26.72	28.28	30.31	32.03	33.51	35.20
		0.82	20.07	18.00	21.13	23.78	26.06	28.06	29.82	32.12	34.08	35.80	37.76
		1.07	33.61	18.27	21.52	24.30	26.71	28.82	30.70	33.16	35.28	37.14	39.28
		1.32	50.49	18.45	21.78	24.64	27.13	29.32	31.28	33.85	36.07	38.02	40.28
		1.42	57.67	18.50	21.85	24.73	27.25	29.47	31.44	34.05	36.30	38.28	40.58

Air Valve	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m^3/h)									
				1529	2039	2549	3058	3398	4078	4757	5437	6116	6800
16	1 Row	0.13	4.10	11.21	12.61	13.75	14.72	15.29	16.29	17.14	17.87	18.52	19.09
		0.19	8.48	12.26	13.90	15.31	16.57	17.33	18.68	19.86	20.90	21.83	22.67
		0.25	14.26	12.86	14.68	16.25	17.65	18.52	20.11	21.51	22.77	23.90	24.93
		0.32	21.39	13.25	15.20	16.89	18.41	19.34	21.06	22.62	24.03	25.32	26.49
		0.38	29.83	13.52	15.56	17.35	18.95	19.95	21.77	23.42	24.95	26.35	27.63
		0.47	44.89	13.80	15.94	17.82	19.53	20.59	22.54	24.32	25.94	27.45	28.87
	2 Row	0.32	3.44	20.13	23.37	25.88	27.88	29.00	30.89	32.41	33.67	34.73	35.64
		0.57	10.45	21.84	25.85	29.08	31.76	33.30	35.94	38.14	39.99	41.59	42.98
		0.82	21.07	22.55	26.92	30.50	33.50	35.25	38.28	40.84	43.02	44.91	46.57
		1.07	35.21	22.95	27.52	31.30	34.50	36.37	39.64	42.41	44.79	46.87	48.71
		1.32	52.82	23.20	27.90	31.82	35.14	37.10	40.53	43.45	45.97	48.18	50.13
		1.42	60.31	23.27	28.01	31.97	35.33	37.31	40.79	43.75	46.32	48.56	50.55

Note: 1, EAT= 12.8°C, EWT= 82.2°C.
2, Capacity based on 12.8°C entering air temperature and 82.2°C entering water temperature. Refer to correction factors for different entering conditions.
Actual Heating capacity = Data in the above table x Temperature Conrection factor

Entering water temperature minus entering air temperature EWT-EAT	22	28	33	39	44	56	69	78	83	89	100	111
Temperature correction factor	032	0.40	0.48	0.56	0.64	0.80	1.0	1.12	1.20	1.29	1.45	1.61

Please use the following equation to calculate the leaving air temperature and the difference between entering water temperature and leaving water temperature.

$$LAT = EAT + \left[\frac{KW \times 2988}{M^3/H \text{ (Air volume)}} \right]$$

Outlet air temperature — Inlet air temperature — Difference between inlet water and outlet water

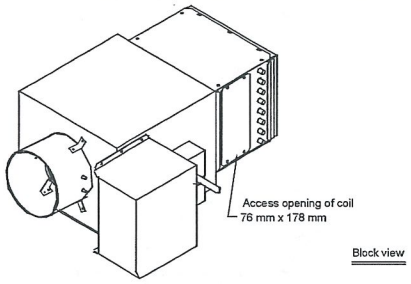
$$WTD = EWT - LWT = \left[\frac{KW}{4.19 \times L/S \text{ (Water volume)}} \right]$$

Inlet water temperature — Outlet water temperature

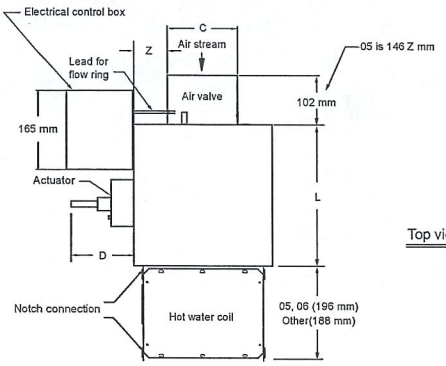
Dimensional Data
VariTrane Single-Duct

Dimension for Single Duct with Hot Water Coil

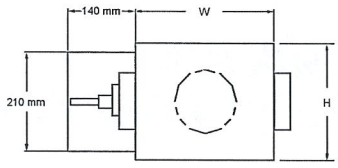
Air Valve	Overall dimension (mm)						
	L	H	W	D	Z	Air outlet dimension	
						A (h)	B (w)
05	292	211	244	127	70	203	254
06	292	211	244	127	70	203	254
08	279	262	269	140	57	254	279
10	305	313	345	127	70	305	356
12	330	364	422	114	83	356	432
14	356	465	472	114	83	457	483
16	381	465	574	89	108	457	584



Block view



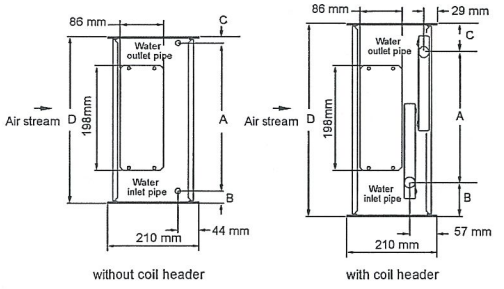
Top view

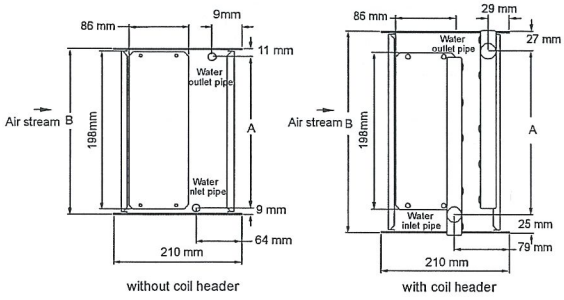


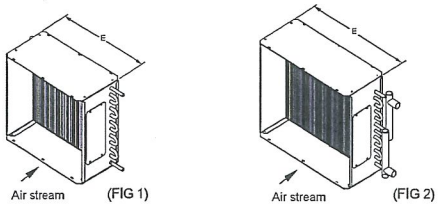
Rear view

Air Valve	Dimension of coil (mm)								
	1 Row						2 Row		
		A	B	C	D	W		A	B
05	without coil header	178	17	13	203	254	with coil header	158	211
06		178	17	13	203	254		158	211
08		229	22	11	254	279		210	257
10		279	22	11	203	356		260	308
12	with coil header	248	64	53	356	432		311	359
14		400	38	27	457	482		413	460
16		400	38	27	457	584		413	460

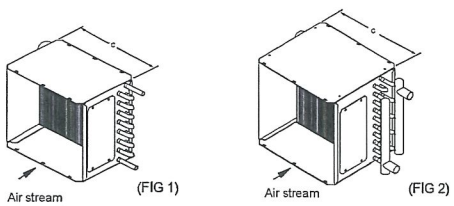
Note: Outer diameter of coil connection for without coil head is 10mm; and Outer diameter of coil for with coil head is 10mm







Single row

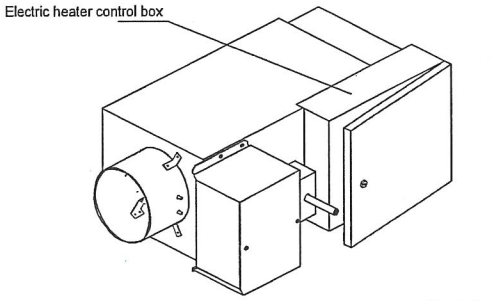


Double row

Dimensional Data
VariTrane Single-Duct

Dimension for Single Duct with Electric Heating

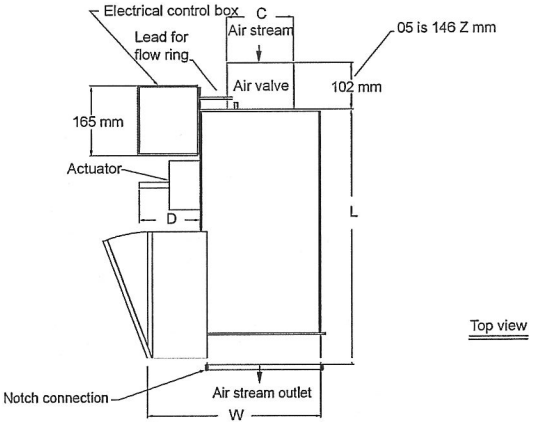
Air Valve	Overall dimension (mm)					
	L	H	W	D	Air outlet dimension	
					A (h)	B (w)
05	1156	241	406	140	203	254
06	1156	241	406	140	203	254
08	1105	292	532	140	254	279
10	1105	343	508	127	305	356
12	1105	394	584	114	356	432
14	1105	495	635	114	457	483
16	1105	495	737	89	457	584



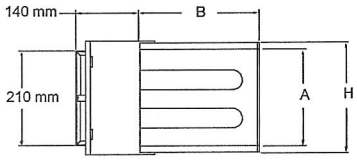
Block view

Electric Heater (kW)

Model	Heating Stages	220V	380V
05	1	1/2/3	2
	2	-	-
	3	-	-
06	1	1/2/3/4	4
	2	-	-
	3	-	-
08	1	1/2/3/4	1/2/4
	2	6/7	6
	3	-	7
10	1	1/2/3/4	1/2/4
	2	6/8	6/8
	3	9	10
12	1	1/2/3/4	1/2/4
	2	6/8	6/8/1
	3	9	12/16
14	1	1/2/3/4	2/4/6
	2	6/8	8/10/12
	3	9	16/18/22
16	1	1/2/3/4	2/4/6
	2	6/8	8/10/12/16
	3	9	18/22/26/30



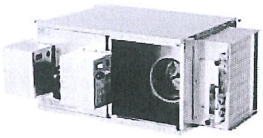
Top view



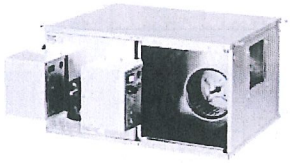
Rear view

Left

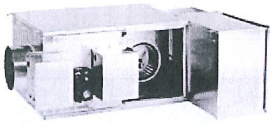
Performance Data
VariTrane Series Fan-Powered



VSCT Series Fan-powered terminal device for cooling only



VSWT Series Fan-Powered terminal device with hot water coil



VSET Series Fan-Powered terminal device with Electric heating

Performance Data

Air Valve	Inlet diameter (mm)	Fan model	Air volume of fan m³/h	Air volume range for primary air m³/h	Overall dimension mm (L × W × H)	Weight (kg)
05	127	02SQ	920	595	994×699×394	35
06	152	02SQ	920	850	994×699×394	35
		03SQ	1580	850	1146×750×445	39
08	203	02SQ	920	920	994×699×394	35
		03SQ	1580	1530	1146×750×445	39
		04SQ	2180	1530	1146×750×445	39
10	254	02SQ	920	920	994×699×394	35
		03SQ	1580	1580	1146×750×445	39
		04SQ	2180	2180	1146×750×445	39
		05SQ	2660	2380	1146×902×445	45
		06SQ	3700	2380	1146×902×546	53
		07SQ	4180	2380	1146×902×546	57
12	305	03SQ	1580	1580	1146×750×445	39
		04SQ	2180	2180	1146×750×445	39
		05SQ	2660	2660	1146×902×445	45
		06SQ	3700	3400	1146×902×546	53
		07SQ	4180	3400	1146×902×546	57
14	356	04SQ	2180	2180	1146×750×445	39
		05SQ	2660	2660	1146×902×445	45
		06SQ	3700	3700	1146×902×546	53
		07SQ	4180	4180	1146×902×546	57
16	406	06SQ	3700	3700	1146×902×546	53
		07SQ	4180	4180	1146×902×546	57

Hot Water Coil (kW)

Fan model	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m³/h)								
				255	340	425	510	595	680	765	850	920
02SQ	1 Row	0.06	1.59	2.68	3.03	3.32	3.58	3.80	4.01	4.20	4.38	4.52
		0.13	5.52	2.91	3.34	3.70	4.02	4.32	4.59	4.84	5.08	5.27
		0.19	11.51	3.00	3.46	3.85	4.20	4.52	4.82	5.10	5.37	5.58
		0.25	19.45	3.05	3.52	3.93	4.30	4.63	4.95	5.25	5.53	5.75
		0.32	29.27	3.08	3.56	3.98	4.36	4.71	5.03	5.34	5.63	5.86
	2 Row	0.06	3.00	3.69	4.46	5.10	5.63	6.08	6.46	6.80	7.09	7.30
		0.13	10.21	3.93	4.86	5.67	6.37	6.99	7.54	8.03	8.47	8.81
		0.19	21.07	4.02	5.01	5.87	6.64	7.33	7.95	8.51	9.02	9.41
		0.25	35.33	4.06	5.08	5.98	6.78	7.51	8.16	8.76	9.31	9.73
		0.32	52.84	4.09	5.12	6.04	6.87	7.62	8.30	8.92	9.50	9.94

TRANE

Performance Data
VariTrane Series Fan-Powered

Hot Water Coil (kW) - contiune

Fan model	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m³/h)								
				340	510	680	934	1189	1444	1580	1954	2180
03SQ /04SQ	1 Row	0.13	3.02	4.40	5.33	6.04	6.91	7.62	8.23	8.53	9.29	9.70
		0.19	6.56	4.60	5.64	6.45	7.45	8.29	9.03	9.39	10.30	10.79
		0.25	11.39	4.71	5.80	6.67	7.75	8.67	9.49	9.89	10.91	11.47
		0.32	17.49	4.77	5.91	6.81	7.94	8.92	9.79	10.21	11.31	11.92
		0.38	24.86	4.82	5.98	6.91	8.08	9.09	10.00	10.44	11.60	12.24
		0.44	33.49	4.85	6.03	6.98	8.18	9.22	10.16	10.62	11.81	12.48
		0.50	43.36	4.88	6.08	7.04	8.26	9.32	10.28	10.75	11.98	12.66
		0.57	54.46	4.90	6.11	7.08	8.32	9.40	10.38	10.86	12.12	12.81
		0.63	66.80	4.92	6.13	7.12	8.37	9.47	10.46	10.94	12.22	12.94
	2 Row	0.13	4.22	5.55	7.50	9.07	10.90	12.31	13.42	13.90	15.06	15.61
		0.19	8.99	5.70	7.83	9.61	11.78	13.52	14.94	15.57	17.13	17.90
		0.25	15.41	5.78	8.00	9.89	12.25	14.18	15.79	16.52	18.33	19.24
		0.32	23.45	5.83	8.10	10.06	12.54	14.60	16.33	17.13	19.12	20.12
		0.38	33.07	5.86	8.17	10.18	12.74	14.88	16.71	17.55	19.67	20.75
		0.44	44.26	5.88	8.22	10.26	12.88	15.09	16.99	17.86	20.07	21.21
		0.50	57.00	5.90	8.26	10.33	12.99	15.25	17.20	18.10	20.39	21.57

Fan model	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m³/h)							
				595	850	1104	1359	1699	2039	2379	2660
05SQ	1 Row	0.13	3.22	6.35	7.40	8.23	8.94	9.76	10.49	11.12	11.59
		0.19	6.95	6.75	7.95	8.94	9.78	10.77	11.64	12.42	13.03
		0.25	12.04	6.96	8.26	9.33	10.27	11.37	12.34	13.23	13.90
		0.32	18.46	7.10	8.46	9.59	10.58	11.76	12.81	13.77	14.50
		0.38	26.20	7.19	8.60	9.77	10.80	12.03	13.14	14.15	14.93
		0.44	35.23	7.26	8.70	9.90	10.97	12.24	13.39	14.44	15.26
		0.50	45.57	7.32	8.78	10.01	11.09	12.40	13.58	14.67	15.51
	2 Row	0.13	4.16	8.78	11.05	12.78	14.16	15.58	16.69	17.57	18.17
		0.19	8.85	9.20	11.83	13.94	15.68	17.57	19.10	20.35	21.23
		0.25	15.17	9.42	12.23	14.56	16.52	18.69	20.48	21.99	23.06
		0.32	23.09	9.55	12.48	14.95	17.04	19.41	21.38	23.07	24.28
		0.38	32.57	9.63	12.65	15.21	17.40	19.90	22.01	23.83	25.14
		0.44	43.60	9.70	12.77	15.39	17.67	20.26	22.48	24.39	25.78
		0.50	56.16	9.74	12.86	15.54	17.87	20.54	22.83	24.82	26.27

Fan model	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m³/h)								
				1189	1529	1869	2209	2549	2888	3228	3568	4060	4180
06SQ /07SQ	1 Row	0.13	4.10	9.15	10.11	10.98	11.74	12.41	13.00	13.54	14.03	14.67	14.82
		0.19	8.46	9.91	11.07	12.07	12.97	13.80	14.58	15.29	15.94	16.81	17.01
		0.25	14.22	10.34	11.61	12.73	13.73	14.66	15.51	16.30	17.07	18.08	18.32
		0.32	21.30	10.61	11.96	13.15	14.23	15.23	16.15	17.02	17.83	18.93	19.19
		0.38	29.68	10.80	12.20	13.45	14.59	15.64	16.62	17.54	18.40	19.57	19.84
	2 Row	0.13	7.71	14.01	15.83	17.23	18.33	19.23	19.97	20.59	21.11	21.75	21.89
		0.19	15.74	15.27	17.61	19.49	21.04	22.33	23.43	24.38	25.20	26.21	26.44
		0.25	26.24	15.94	18.58	20.75	22.58	24.14	25.49	26.67	27.71	29.00	29.29
		0.32	39.08	16.34	19.18	21.55	23.58	25.32	26.85	28.19	29.38	30.88	31.23
		0.38	54.19	16.62	19.59	22.11	24.27	26.15	27.80	29.27	30.58	32.24	32.62

Note: Leaving water temperature of hot water coil LWT should not exceed 60°C.
Heating capacity is based on entering air temperature of 21°C and entering water temperature of 82°C. Refer to correction factors different entering condifions, actual heating capacity = data in the table above × temperature correction factor

Entering water temperature minus entering air temperature EWT-EAT	22	27	33	38	44	50	55	61	67	72
Correction factor	0.355	0.446	0.537	0.629	0.722	0.814	0.907	1.000	1.093	1.187

By using the following equation, Leaving air temperature LAT and difference between entering water temperature and leaving water WTD temperature can be calculated.

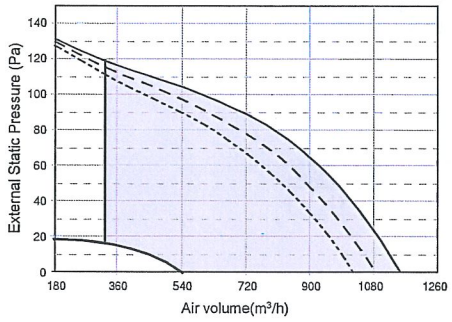
$$LAT = EAT + \left[\frac{KW \times 2988}{M^3/H\ (\text{Air volume})}\right] \qquad WTD = EWT - LWT = \left[\frac{KW}{4.19 \times L/S\ (\text{Water volume})}\right]$$

LAT: Outlet air temperature; EAT: Inlet air temperature; WTD: Difference between inlet water and outlet water; EWT: Entering water temperature; LWT: Leaving water temperature

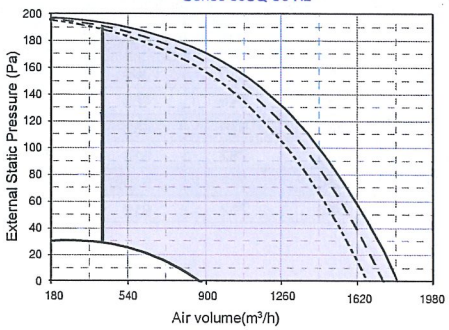
Performance Data
VariTrane Series Fan-Powered

Series Fan Curve

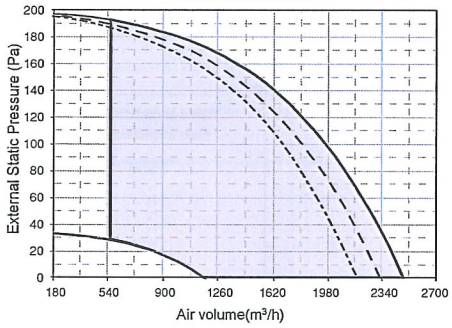
Series 02SQ-50 Hz



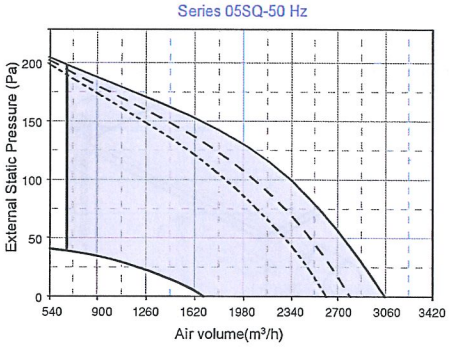
Series 03SQ-50 Hz



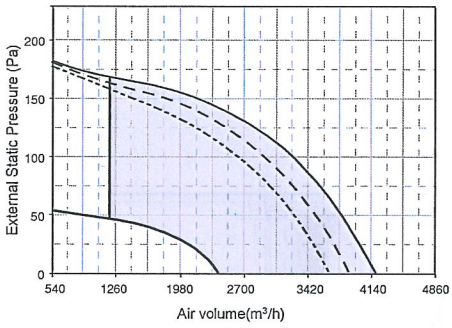
Series 04SQ-50 Hz



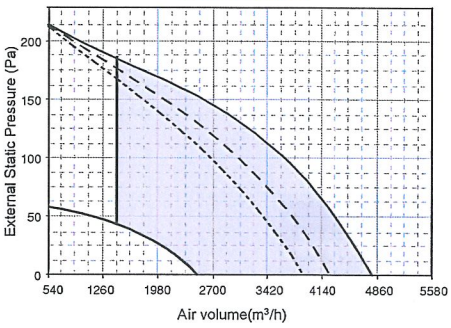
Series 05SQ-50 Hz

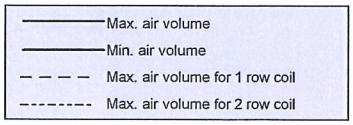


Series 06SQ-50 Hz



Series 07SQ-50 Hz

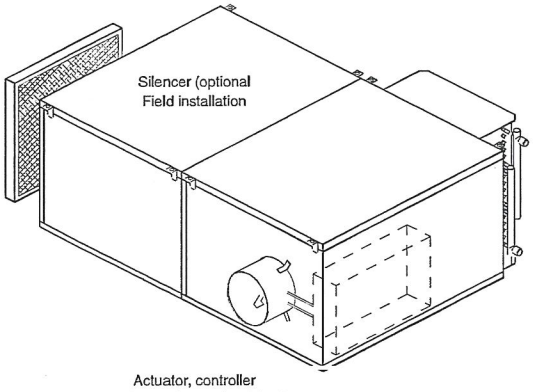




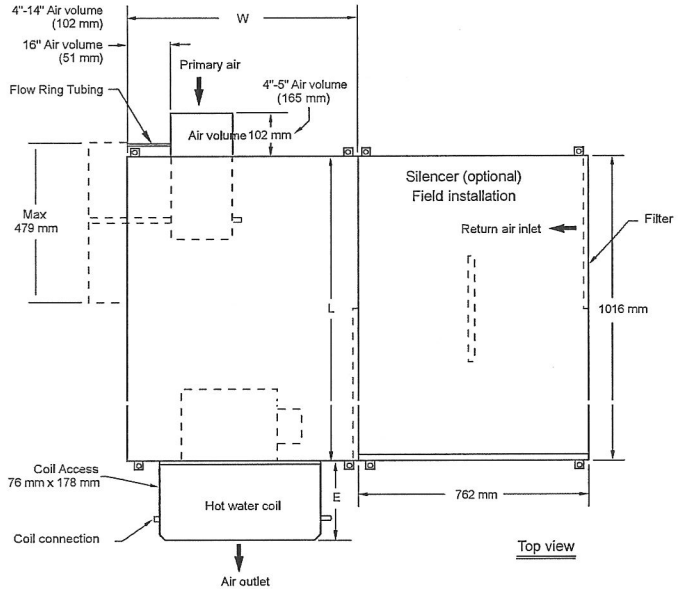
Dimensional Data
VariTrane Series Fan-Powered

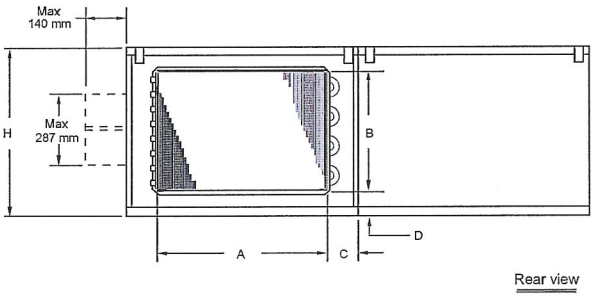
Dimension for Series Fan Powered with Hot Water Coil

Fan model	Overall dimension (mm)							
	L	H	W	Air outlet dimension		C	D	E
				A (h)	B (w)			
02SQ	864	394	559	305	356	127	17	171
03SQ	1016	445	610	483	406	64	19	273
04SQ	1016	445	610	483	406	64	19	273
05SQ	1016	445	762	610	406	76	19	273
06SQ	1016	546	762	610	457	76	42	171
07SQ	1016	546	762	610	457	76	42	171



Actuator, controller
and electrical controls of the fan



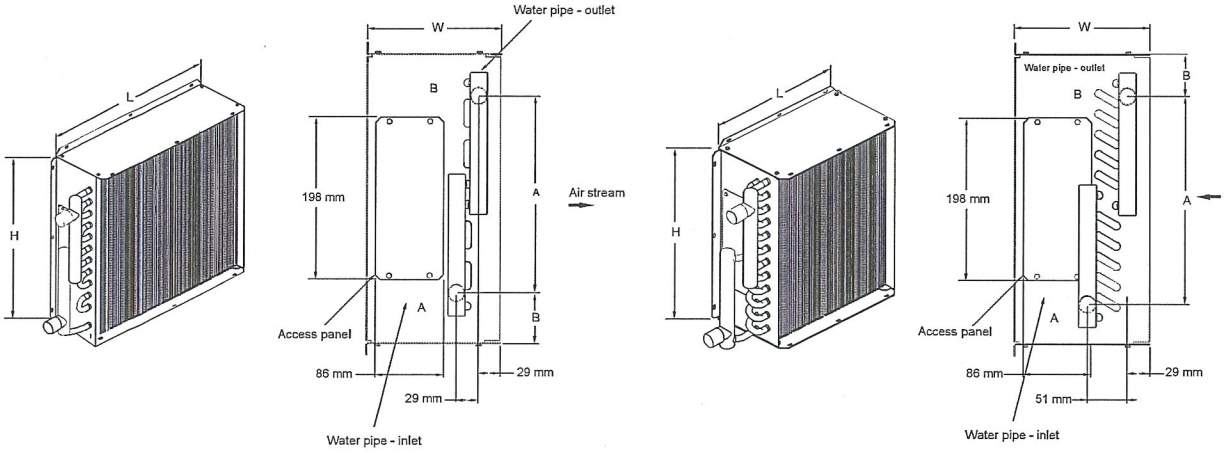


Fan model	Filter Size (standard configuration)
02SQ	356 mm x 356 mm x 15 mm
03SQ 04SQ 05SQ	406 mm x 508 mm x 15 mm
06SQ 07SQ	508 mm x 508 mm x 15 mm

Dimensional Data
VariTrane Series Fan-Powered

Dimension for Hot Water Coil

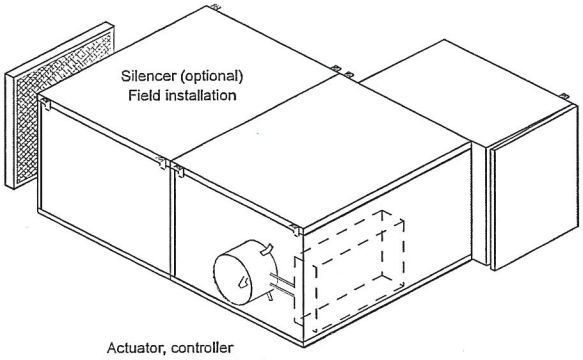
Fan model	Dimension of coil (mm)									
	1 Row					2 Row				
	A	B	L	H	W	A	B	L	H	W
02SQ	248	51	310	356	171	260	51	310	356	171
03SQ	349	51	533	406	273	349	51	533	406	273
04SQ	349	51	533	406	273	349	51	533	406	273
05SQ	349	51	610	406	273	349	51	610	406	273
06SQ	400	25	610	457	171	400	25	610	457	171
07SQ	400	25	610	457	171	400	25	610	457	171



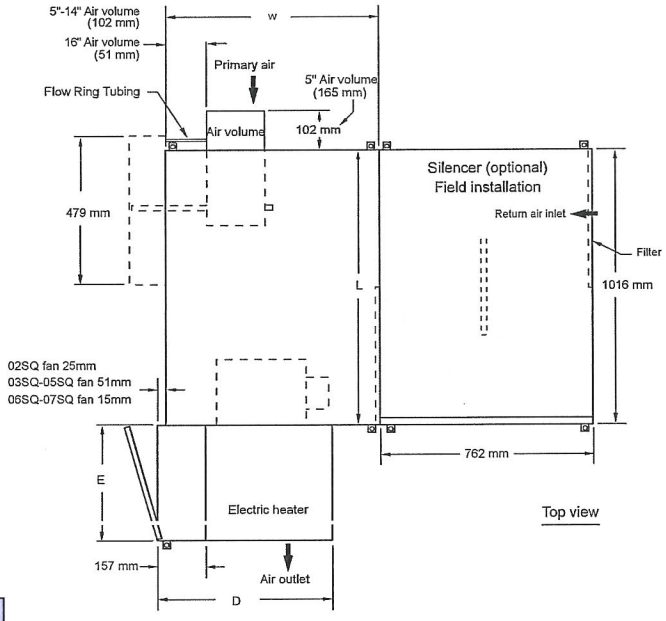
Dimensional Data
VariTrane Series Fan-Powered

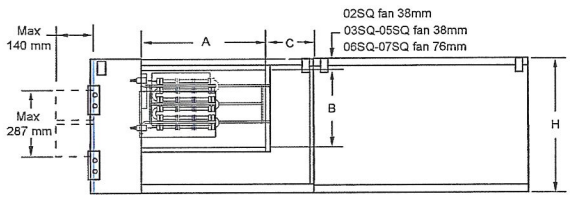
Dimension for Series Fan-Powered with Electric Heating

Fan model	Overall dimension (mm)							
	L	H	W	Air outlet dimension		C	D	E
				A (h)	B (w)			
02SQ	864	394	559	305	254	127	457	470
03SQ	1016	445	610	305	305	102	457	470
04SQ	1016	445	610	406	305	102	559	470
05SQ	1016	445	762	406	305	254	559	470
06SQ	1016	546	762	483	356	140	635	432
07SQ	1016	546	762	483	356	140	635	432



Actuator, controller
and electrical controls of the fan





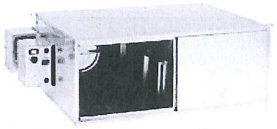
Rear view

Electric Heater (kW)

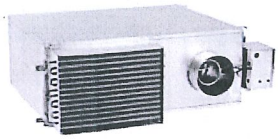
Model	Heating Stages	220V	380V
02SQ	1	1/2/3/4	1/2/3/4
	2	6	6
03SQ	1	1/2/3/4	1/2/3/4
	2	6/8	6/8/10
04SQ	1	1/2/3/4	1/2/3/4
	2	6/8	8/10/12/14
05SQ	1	1/2/3/4	2/4/6/8
	2	6/8	10/12/14/16
06SQ	1	1/2/3/4	2/4/6/8
	2	6/8	10/12/14/16/20
07SQ	1	1/2/3/4	2/4/6/8
	2	6/8	10/12/16/20

Fan model	Filter Size (standard configuration)
02SQ	356 mm x 356 mm x 15 mm
03SQ 04SQ 05SQ	406 mm x 508 mm x 15 mm
06SQ 07SQ	508 mm x 508 mm x 15 mm

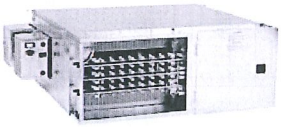
Performance Data
VariTrane Parallel Fan-Powered



VPCT Parallel Fan-Powered terminal device for cooling only



VPWT Parallel Fan-Powered terminal device with hot water coil



VPET Parallel Fan-Powered terminal device with electric heating

Performance Data

Air valve	Inlet diameter (mm)	Fan model	Air volume of fan m³/h	Air volume range for primary air m³/h	Overall dimension mm (L × W × H)	Weight (kg)
05	127	02SQ	320	68-595	864×1156×394	35
06	152	02SQ	320	101-850	864×1156×394	35
		03SQ	1470	101-850	927×1156×445	43
08	203	02SQ	320	180-1530	864×1156×394	35
		03SQ	1470	180-1530	927×1156×445	43
		04SQ	1830	180-1530	927×1156×445	44
10	254	02SQ	320	277-2380	64×1156×394	35
		03SQ	1470	277-2380	927×1156×445	43
		04SQ	1830	277-2380	927×1156×445	44
		05SQ	1900	277-2380	927×1156×445	50
		06SQ	2300	277-2380	1118×1156×546	53
		07SQ	2550	277-2380	1118×1156×546	57
12	305	03SQ	1470	400-3400	927×1156×445	43
		04SQ	1830	400-3400	927×1156×445	44
		05SQ	1900	400-3400	927×1156×445	50
		06SQ	2300	400-3400	1118×1156×546	53
		07SQ	2550	400-3400	1118×1156×546	57
14	356	04SQ	1830	544-5100	927×1156×445	44
		05SQ	1900	544-5100	927×1156×445	50
		06SQ	2300	544-5100	1118×1156×546	53
		07SQ	2550	544-5100	1118×1156×546	57
16	406	06SQ	2300	713-6800	1118×1156×546	53
		07SQ	2550	713-6800	1118×1156×546	57

Performance Data
VariTrane Parallel Fan-Powered

Hot Water Coil Performance Data (kW)

Fan model	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m³/h)										
				170	255	340	425	510	595	680	765	850	934	1020
02SQ	1 Row	0.03	0.66	2.41	2.67	3.24	3.51	3.73	3.92	4.07	4.20	4.32	4.42	4.51
		0.06	2.26	2.69	3.37	3.85	4.24	4.56	4.84	5.09	5.32	5.55	5.76	5.95
		0.13	7.91	2.87	3.66	4.26	4.74	5.16	5.53	5.87	6.18	6.47	6.75	7.00
		0.19	16.57	2.93	3.77	4.41	4.93	5.39	5.80	6.18	6.52	6.85	7.16	7.46
		0.25	28.08	2.97	3.83	4.49	5.04	5.52	5.95	6.34	6.71	7.06	7.39	7.71
		0.32	42.34	2.99	3.87	4.54	5.10	5.59	6.04	6.45	6.83	7.19	7.53	7.86
	2 Row	0.06	3.89	2.92	4.05	5.00	5.80	6.49	7.07	7.58	8.02	8.40	8.74	9.05
		0.13	13.19	3.02	4.27	5.39	6.38	7.27	8.08	8.80	9.46	10.06	10.60	11.11
		0.19	27.13	3.05	4.35	5.52	6.58	7.55	8.43	9.24	9.99	10.68	11.32	11.92
		0.25	45.38	3.06	4.38	5.58	6.68	7.69	8.62	9.47	10.27	11.01	11.70	12.35
		0.32	67.73	3.07	4.40	5.62	6.74	7.77	8.73	9.61	10.44	11.21	11.93	12.61

Fan model	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m³/h)										
				255	510	765	1019	1274	1529	1784	2039	2294	2549	2804
03SQ /04SQ /05SQ	1 Row	0.06	0.82	3.49	4.72	5.45	6.03	6.49	6.86	7.18	7.45	7.69	7.90	8.09
		0.13	3.06	3.85	5.46	6.51	7.33	8.02	8.62	9.17	9.67	10.12	10.53	10.91
		0.19	6.63	3.99	5.77	6.97	7.93	8.75	9.48	10.14	10.74	11.29	11.81	12.31
		0.25	11.51	4.07	5.94	7.22	8.27	9.17	9.97	10.71	11.38	12.01	12.60	13.15
		0.32	17.68	4.11	6.05	7.39	8.48	9.44	10.30	11.08	11.81	12.49	13.13	13.73
		0.38	25.13	4.15	6.12	7.50	8.64	9.63	10.53	11.35	12.12	12.84	13.51	14.15
		0.44	33.83	4.17	6.18	7.58	8.75	9.77	10.70	11.55	12.35	13.09	13.80	14.47
		0.50	43.79	4.19	6.22	7.65	8.83	9.88	10.83	11.71	12.52	13.29	14.02	14.71
		0.57	55.00	4.20	6.25	7.70	8.90	9.97	10.93	11.83	12.67	13.46	14.20	14.91
		0.63	67.45	4.21	6.28	7.74	8.96	10.04	11.02	11.93	12.78	13.59	14.35	15.08
	2 Row	0.06	1.06	4.10	6.52	8.01	9.06	9.78	10.31	10.70	11.02	11.27	11.48	11.65
		0.13	3.83	4.42	7.58	9.88	11.60	12.93	14.00	14.87	15.59	16.20	16.73	17.18
		0.19	8.20	4.50	7.91	10.53	12.60	14.27	15.65	16.81	17.80	18.66	19.40	20.07
		0.25	14.11	4.54	8.08	10.88	13.14	15.01	16.58	17.92	19.09	20.11	21.01	21.81
		0.32	21.52	4.57	8.18	11.09	13.47	15.47	17.17	18.64	19.92	21.06	22.07	22.97
		0.38	30.42	4.58	8.25	11.23	13.70	15.79	17.58	19.14	20.51	21.73	22.82	23.81
		0.44	40.78	4.60	8.30	11.33	13.87	16.02	17.88	19.51	20.95	22.23	23.39	24.43
		0.50	52.59	4.61	8.33	11.41	13.99	16.20	18.12	19.80	21.29	22.62	23.82	24.91
		0.57	65.84	4.61	8.36	11.47	14.09	16.34	18.30	20.02	21.56	22.93	24.17	25.30
		0.63	80.52	4.62	8.39	11.52	14.17	16.45	18.45	20.21	21.77	23.18	24.46	25.62

Fan model	Coil Rows	Water volume (L/s)	Water pressure drop (kPa)	Air volume (m³/h)										
				1529	1699	1869	2039	2209	2379	2549	2718	2888	3058	3230
06SQ /07SQ	1 Row	0.03	0.33	5.18	5.27	5.35	5.42	5.48	5.54	5.59	5.64	5.68	5.72	5.76
		0.06	1.09	7.74	7.98	8.20	8.41	8.59	8.76	8.91	9.06	9.20	9.32	9.44
		0.13	3.71	9.43	9.85	10.24	10.60	10.94	11.26	11.57	11.86	12.13	12.39	12.64
		0.19	7.68	10.29	10.77	11.23	11.66	12.06	12.46	12.84	13.21	13.56	13.90	14.22
		0.25	12.92	10.78	11.31	11.82	12.30	12.75	13.19	13.61	14.01	14.40	14.78	15.15
		0.32	19.39	11.10	11.66	12.20	12.71	13.20	13.67	14.13	14.57	14.99	15.40	15.79
		0.38	27.04	11.32	11.91	12.47	13.01	13.52	14.02	14.50	14.96	15.40	15.84	16.26
		0.44	35.84	11.48	12.09	12.67	13.23	13.76	14.27	14.77	15.25	15.72	16.17	16.61
	2 Row	0.06	2.02	11.26	11.57	11.84	12.06	12.26	12.43	12.58	12.71	12.83	12.93	13.03
		0.13	6.70	14.96	15.64	16.25	16.80	17.28	17.72	18.12	18.48	18.82	19.12	19.40
		0.19	13.65	16.60	17.51	18.33	19.07	19.74	20.36	20.93	21.45	21.94	22.39	22.81
		0.25	22.70	17.51	18.54	19.49	20.36	21.15	21.89	22.57	23.20	23.80	24.35	24.87
		0.32	33.76	18.07	19.20	20.23	21.18	22.06	22.88	23.64	24.35	25.02	25.64	26.23
		0.38	46.74	18.46	19.65	20.75	21.76	22.70	23.58	24.39	25.16	25.88	26.56	27.20
		0.44	61.61	18.75	19.98	21.12	22.18	23.17	24.09	24.95	25.76	26.52	27.24	27.93

Note: Leaving water temperature of hot water coil LWT should not exceed 60°C.

Heating capacity is based on entering air temperature of 21°C and entering water temperature of 82°C. Refer to correction factors for different entering condifions, actual heating capacity = data in the table above × temperature correction factor

In case the data required by customer exceeds the range in the table, please contact our technical support.

Entering water temperature minus entering air temperature EWT-EAT	22	27	33	39	44	50	55	61	67	72
Correction factor	0.355	0.446	0.537	0.629	0.722	0.814	0.907	1.000	1.093	1.187

By using the following equation, Leaving air temperature LAT and difference between entering water temperature and outlet water temperature WTD can be calculated.

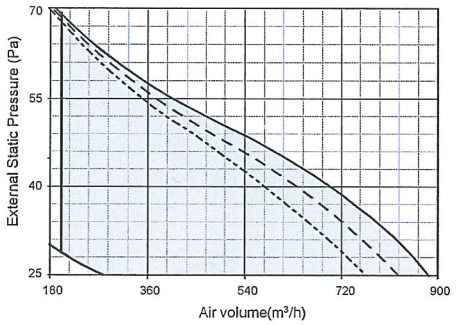
$$LAT = EAT + \left[\frac{KW \times 2988}{M^3/H\ (\text{Air volume})}\right] \qquad WTD = EWT - LWT = \left[\frac{KW}{4.19 \times L/S\ (\text{Water volume})}\right]$$

LAT: Outlet air temperature; EAT: Inlet air temperature; WTD: Difference between inlet water and outlet water; EWT: Entering water temperature; LWT: Leaving water temperature

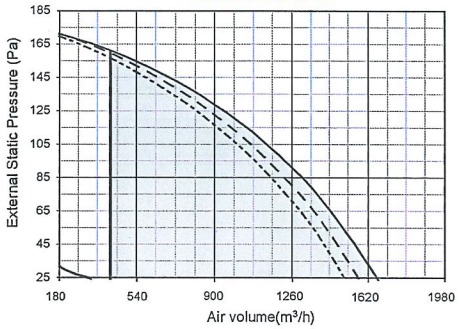
Performance Data
VariTrane Parallel Fan-Powered

Parallel Fan Curve

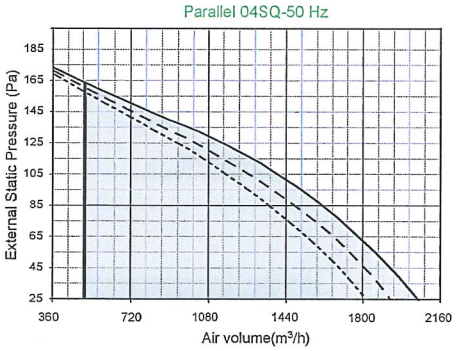
Parallel 02SQ-50 Hz



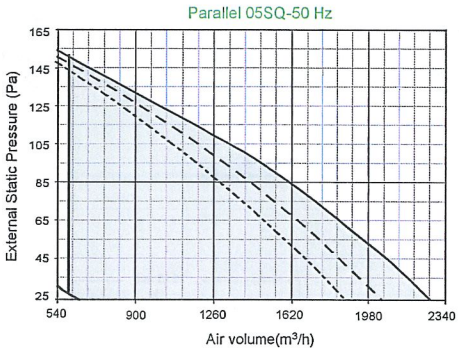
Parallel 03SQ-50 Hz



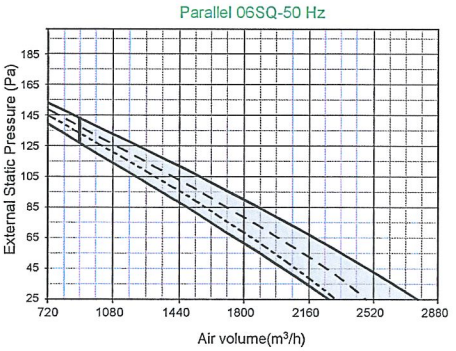
Parallel 04SQ-50 Hz



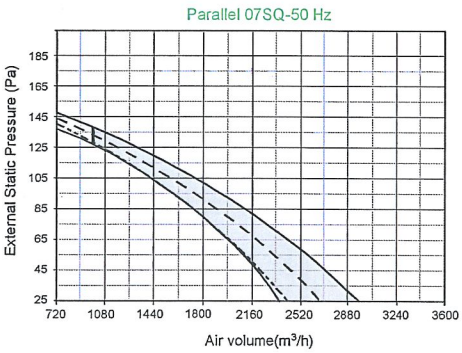
Parallel 05SQ-50 Hz

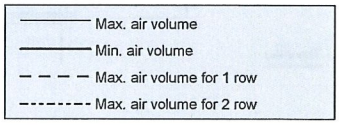


Parallel 06SQ-50 Hz



Parallel 07SQ-50 Hz

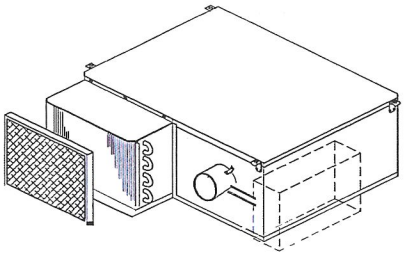




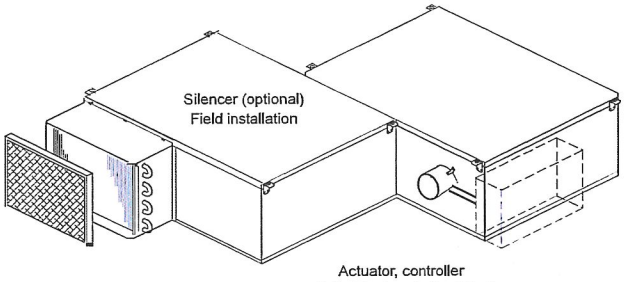
Dimensional Data
VariTrane Parallel Fan-Powered

Dimension for Parallel Fan-Powered with Hot Water Coil – Coil at Return Air Inlet

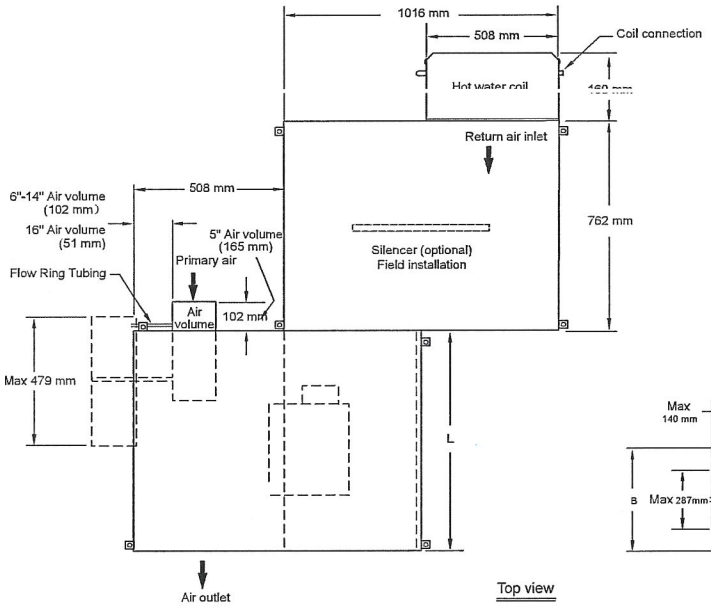
Fan model	Overall dimension (mm)				
	L	H	W	Air outlet dimension	
				A (h)	B (w)
02SQ	762	394	1016	489	356
03SQ	826	445	1016	489	406
04SQ	826	445	1016	489	406
05SQ	826	445	1016	489	406
06SQ	1016	546	1016	489	508
07SQ	1016	546	1016	489	508



Actuator, controller
and electrical controls of the fan

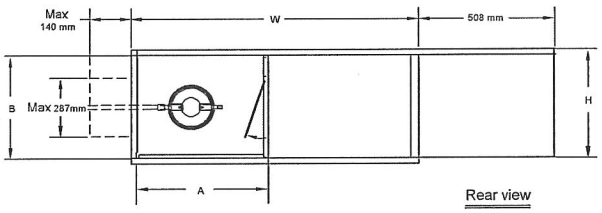


Actuator, controller
and electrical controls of the fan



Top view

Fan model	Filter Size (standard configuration)
02SQ	356 mm x 508 mm x 15 mm
03SQ 04SQ 05SQ	406 mm x 508 mm x 15 mm
06SQ 07SQ	508 mm x 508 mm x 15 mm

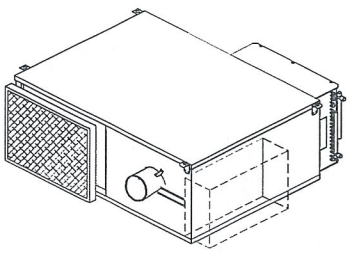


Rear view

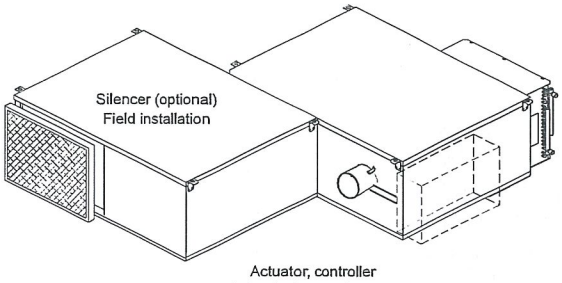
Dimensional Data
VariTrane Parallel Fan-Powered

Dimension for Parallel Fan-Powered Hot Water Coil – Coil at Air Outlet

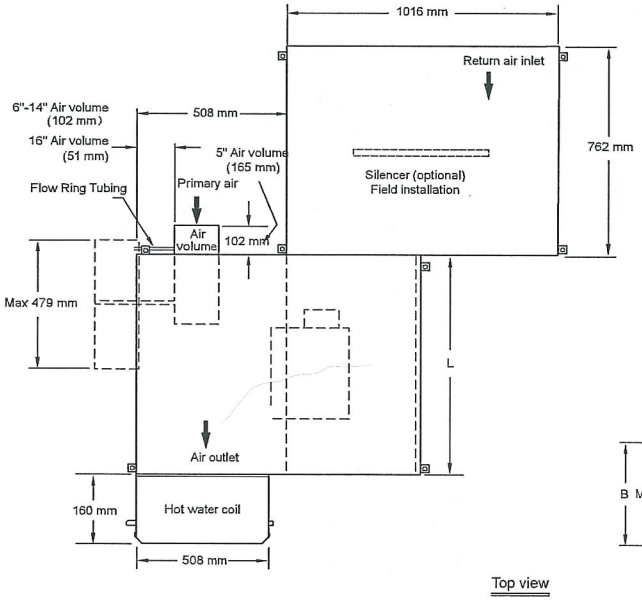
Fan model	Overall dimension (mm)				
	L	H	W	Air outlet dimension	
				A (h)	B (w)
02SQ	762	394	1016	508	356
03SQ	826	445	1016	508	406
04SQ	826	445	1016	508	406
05SQ	826	445	1016	508	406
06SQ	1016	546	1016	508	508
07SQ	1016	546	1016	508	508



Actuator, controller
and electrical controls of the fan

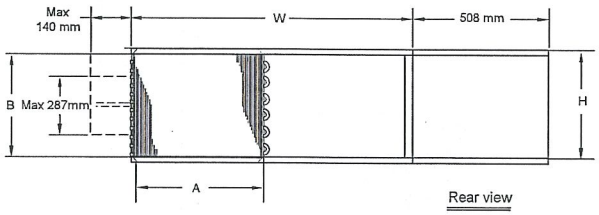


Actuator, controller
and electrical controls of the fan



Top view

Fan model	Filter size (standard configuration)
02SQ	356 mm x 508 mm x 15 mm
03SQ 04SQ 05SQ	406 mm x 508 mm x 15 mm
06SQ 07SQ	508 mm x 508 mm x 15 mm

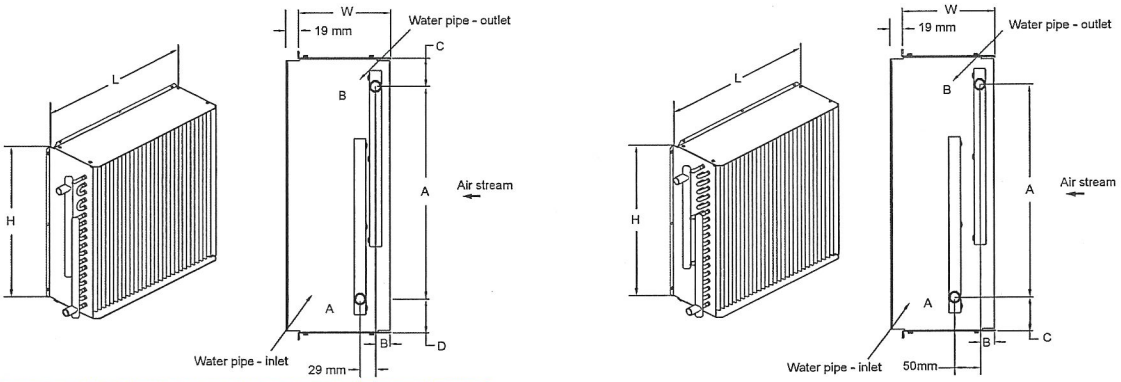


Rear view

Dimensional Data
VariTrane Parallel Fan-Powered

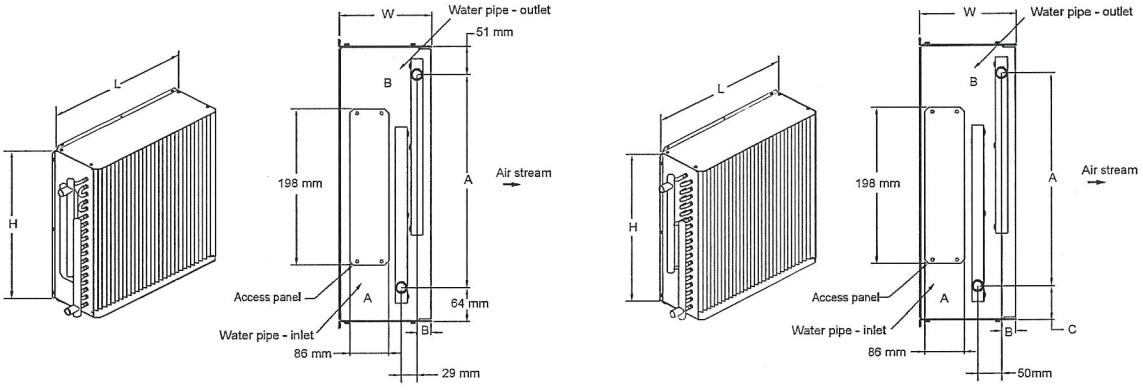
Dimension for Hot Water Coil at Air Inlet

Fan model	Dimension of coil (mm)												
	1 Row							2 Row					
	A	B	C	D	L	H	W	A	B	C	L	H	W
02SQ	248	33	51	64	513	359	171	260	32	173	513	359	171
03SQ	349	25	25	38	508	406	160	349	25	170	508	406	160
04SQ	349	25	25	38	508	406	160	349	25	170	508	406	160
05SQ	349	25	25	38	508	406	160	349	25	170	508	406	160
06SQ	400	32	51	64	513	513	171	400	28	173	513	513	171
07SQ	400	32	51	64	513	513	171	400	28	173	513	513	171



Dimension for Hot Water Coil at Air Outlet

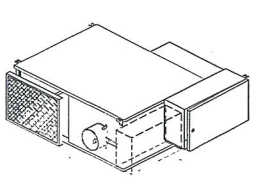
Fan model	Dimension of coil (mm)											
	1 Row					2 Row						
	A	B	L	H	W	A	B	C	D	L	H	W
02SQ	248	41	513	359	171	248	41	173	51	513	359	171
03SQ	349	41	508	406	160	349	25	170	25	508	406	160
04SQ	349	41	508	406	160	349	25	170	25	508	406	160
05SQ	349	41	508	406	160	349	25	170	25	508	406	160
06SQ	400	41	513	513	171	400	32	173	51	513	513	171
07SQ	400	41	513	513	171	400	32	173	51	513	513	171



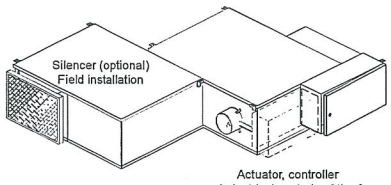
Dimensional Data
VariTrane Parallel Fan-Powered

Dimension of Parallel Fan-Powered with Heater

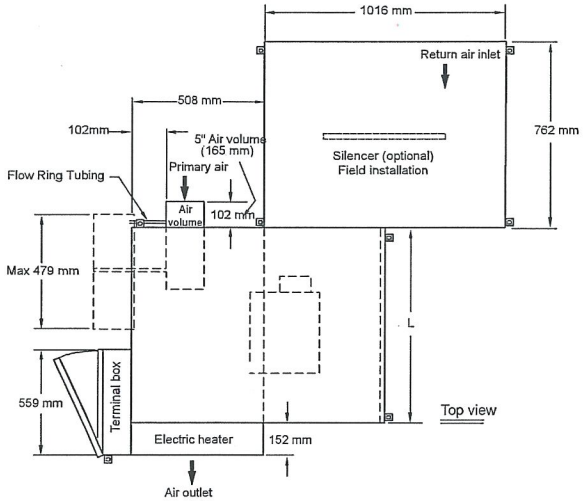
Fan model	Overall dimension (mm)				
	L	H	W	Air outlet dimension	
				A (h)	B (w)
02SQ	762	394	1016	508	356
03SQ	826	445	1016	508	406
04SQ	826	445	1016	508	406
05SQ	826	445	1016	508	406
06SQ	1016	546	1016	508	508
07SQ	1016	546	1016	508	508



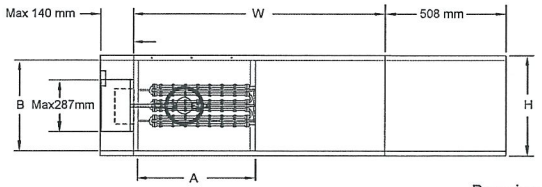
Actuator, controller and electrical controls of the fan



Actuator, controller and electrical controls of the fan

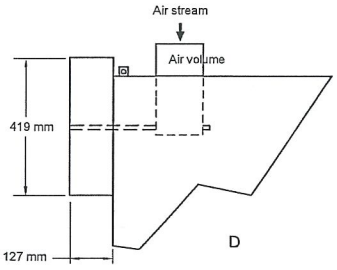


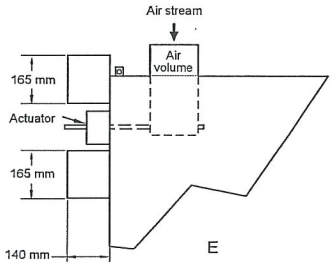
Fan model	Filter Size (standard configuration)
02SQ	356 mm x 508 mm x 15 mm
03SQ 04SQ 05SQ	406 mm x 508 mm x 15 mm
06SQ 07SQ	508 mm x 508 mm x 15 mm



Rear view

Outline Schematic of Electrical Control Box





Control type		DD01-DD04	DD011-DD014	FM00
Fan model	02SQ	D	D	D
	03SQ 04SQ 05SQ	D	D	D
	06SQ 07SQ	E	D	D

Electric Heater (kW)

Model	Heating stages	220V	380V
02SQ	1	1/2/3	1/2/3
	2	-	-
03SQ	1	1/2/3/4	1/2/3/4
	2	6/8	6/8
04SQ	1	1/2/3/4	1/2/4/6
	2	6/8	8/10/12
05SQ	1	1/2/3/4	1/2/4/6
	2	6/8	8/10/12/14
06SQ	1	1/2/3/4	1/2/4/6
	2	6/8	8/10/12
07SQ	1	1/2/3/4	2/4/6/8
	2	6/8	10/12/14/16



Literature Order Number VAV-PRC010-EN

Date March 2008

Supersedes November 2007

www.trane.com

For more information, contact your local Trane office or e-mail us at comfort@trane.com

Trane has a policy of continuous product and data improvement and reserves the right to change design specific ations without notice.