Advanced Energy Saving Through The Use Of Evaporative Cooling And Energy Recovery In Hybrid HVAC Systems

- **Industrial Process And Energy Optimization**
- Industry Workshop
  February 25 - 27, 2004
  Gettysburg, PA
- Leon E. Shapiro
  ADA Systems, LLC
  Carol Stream, IL

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
25 FEB 2004	**N/A**	**-**

4. TITLE AND SUBTITLE	
Advanced Energy Saving Through The Use Of Evaporative Cooling And Energy Recovery In Hybrid HVAC Systems	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **ADA Systems, LLC**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001865, Industrial Process and Energy Optimization. Proceedings of the Industry Workshop Held in Gettysburg, PA, 25-27 February 2004., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**78**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Evaporative Cooling:

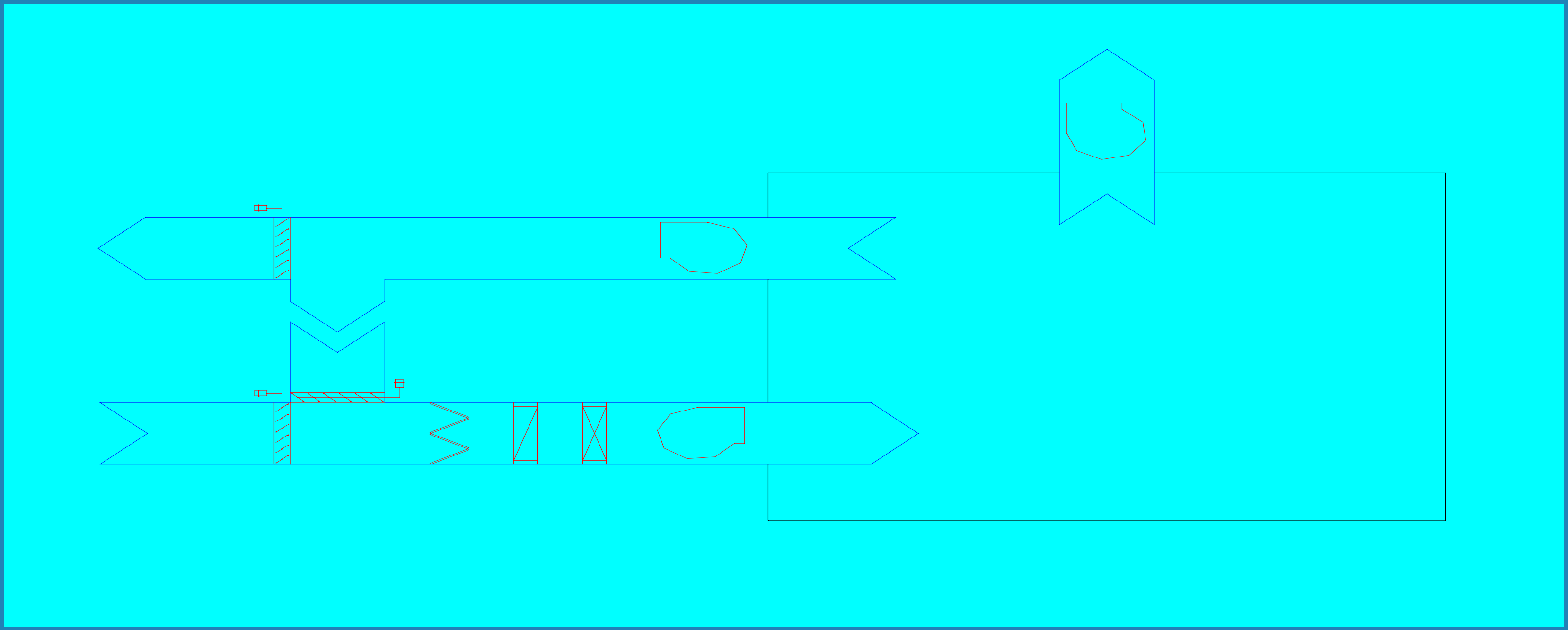
Why Is This Important To You (and your clients)?

- There are external forces affecting the method and manner in which institutions and businesses provide ventilation, heating and cooling for their facilities:
  - ASHRAE Standard 62 - 2001
  - ASHRAE Standard 90.1 - 1999
  - Federal Energy Policy Act of 1992
  - LEED Certification
  - Global Climate Change Treaty
  - Current Events

Evaporative Cooling:
Why Is This Important To You (and your clients)?

- If you could, would you provide your clients/customers with an HVAC system that:
  - Supplies **100% fresh outdoor** air instead of stale recirculated air
  - Uses significantly **less energy** to operate than current recirculation systems
  - Can be installed on a **first cost** basis **equal to** or less than a standard mechanical system
  - Can be **retrofitted** to their existing systems (in most cases)
  - Is **user-friendly** for maintenance personnel to operate and maintain
- If you could, you should…so let's see how….

Evaporative Cooling:
Typical (Non-Evaporative) System



- Based on using **minimum** outside supply air, and recirculating a majority of the building return (exhaust) air

Evaporative Cooling:
Typical (Non-Evaporative) System

- Weaknesses of the Typical System:
  - Recirculation causes internally generated contaminants to become concentrated and spread to all spaces served by the system
  - Ventilation air is not managed properly
  - The process is open loop on latent heat
  - The scheme is predicated on using virgin energy to achieve psychrometric state point changes.
  - The process is predicated on using energy intensive components

Evaporative Cooling:
What Does "Green" Mean To HVAC?

- "Green" is not installing a high efficiency boiler or alternative refrigerant chiller
- "Green" is avoiding the need for that boiler or chiller (or at least significantly downsizing them)
- "Green" is designing a high efficiency **hybrid system** that used high efficiency components

Evaporative Cooling:
“Green” Strategies For HVAC

- **Dual Path Ventilation** - Separation of ventilation from heating and cooling processes permits elimination of terminal reheat and effective management of ventilation
- **Energy Recovery** - Recycling heating/cooling energy permits ventilation air to be introduced into space at low thermodynamic cost
- **Evaporative Cooling and Humidification** - Evaporative processes are the only processes which can close the loop on latent energy. They permit the avoidance of most cooling and humidification energy, and **are** applicable in **all** environments

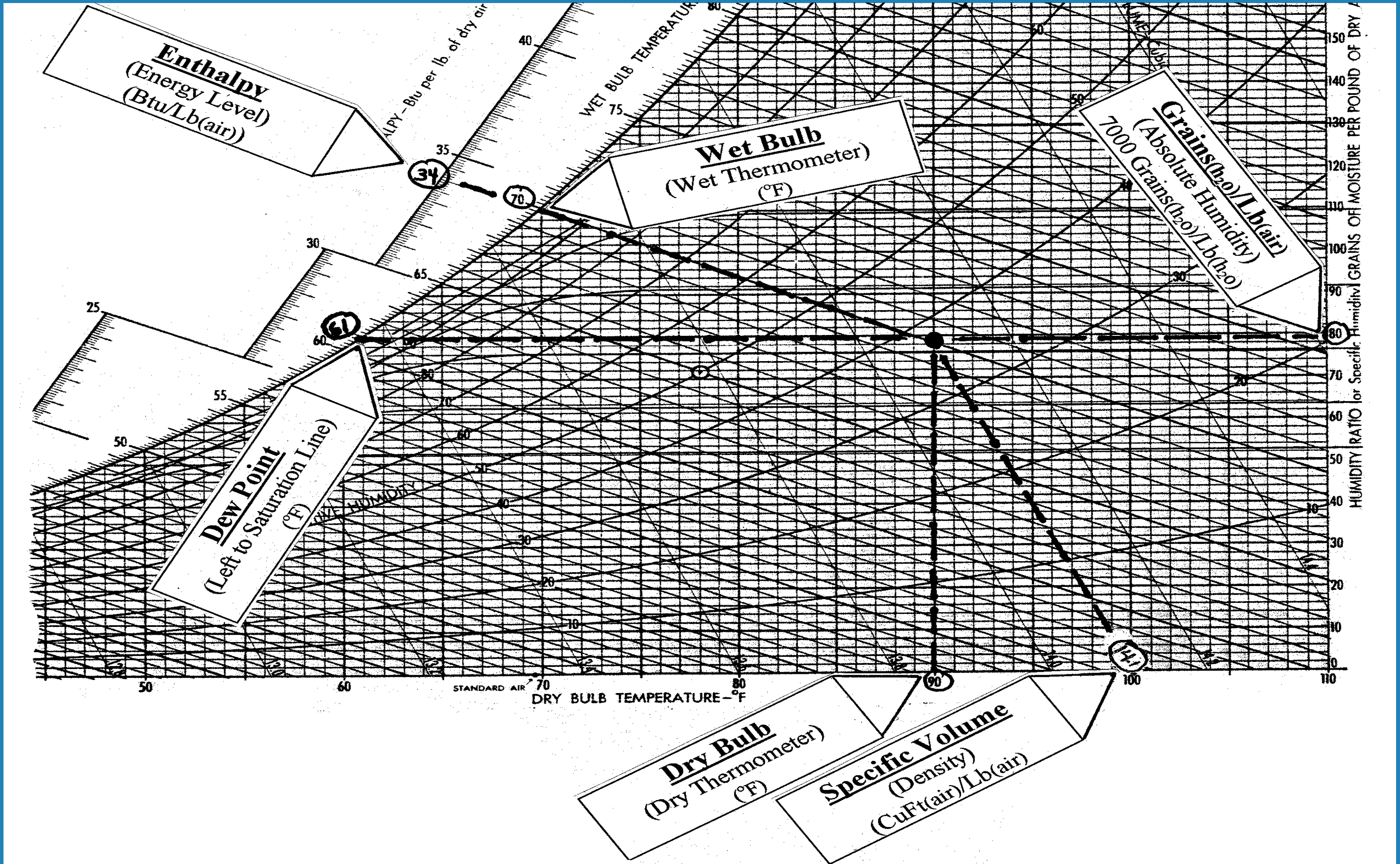
Evaporative Cooling:
"Green" Strategies For HVAC

- **Displacement Ventilation** - Permits small, 100% outside air systems to replace much larger systems and greatly reduce energy use
- **Thermal Storage** - Properly employed, thermal storage can sharply reduce both the quantity and cost of heating and cooling energy use
- **Process Synergism** - Synergism can be created between two processes to achieve more out of them than either process could provide alone

Evaporative Cooling:
"Green" Strategies For HVAC

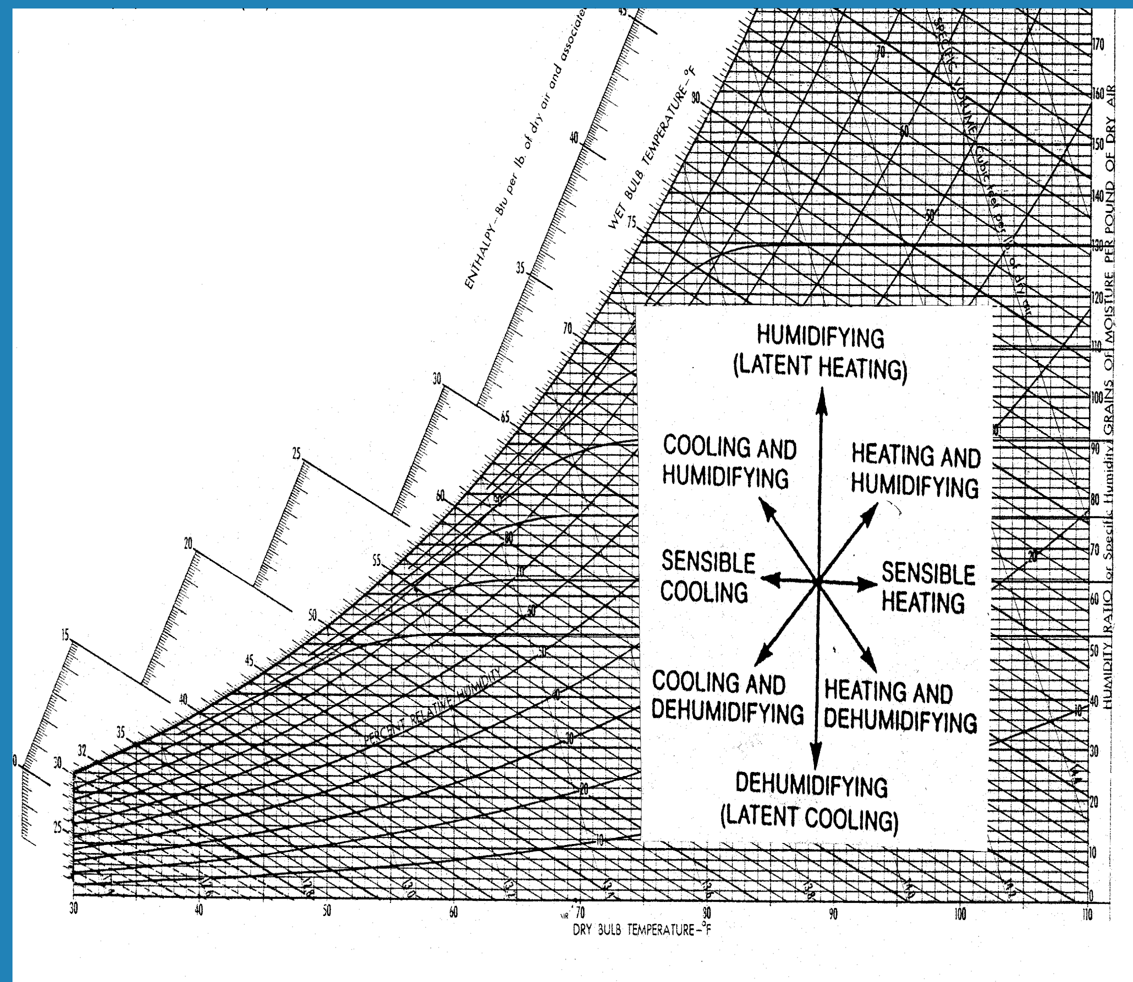
- **Multi-Functional Process Use** - Individual pieces of equipment can be used to serve multiple design objectives. This reduces the parasitic losses systems see from equipment not in use but which require energy to overcome.
- **Amplification** - Multiple heat exchangers can be used to amplify cooling/heating energy for recovery while simultaneously eliminating the need for terminal reheat
- **Avoidance** - Use of recoverable or "free" thermal resources before expending new energy resources

Evaporative Cooling:
Understanding The Psychrometric Chart



Evaporative Cooling:
Understanding The Psychrometric Chart

- All psychrometric processes can be seen as a combination of:
  - Cooling
  - Heating
  - Humidifying
  - Dehumidifying



Evaporative Cooling: Multiple Forms and Technologies

- Evaporative cooling technologies form the backbone of energy efficient hybrid HVAC systems
- There are 2 forms of evaporative cooling
  - **Direct**
    - Draws warm air through a wetted media
  - **Indirect**
    - Utilizes a heat exchanger to separate the supply air from the water used for evaporation
    - Uses a secondary air stream to reject heat from the evaporation process

Evaporative Cooling: Direct Evaporative Cooling Cycle

"Effectiveness" is defined by the following equation:

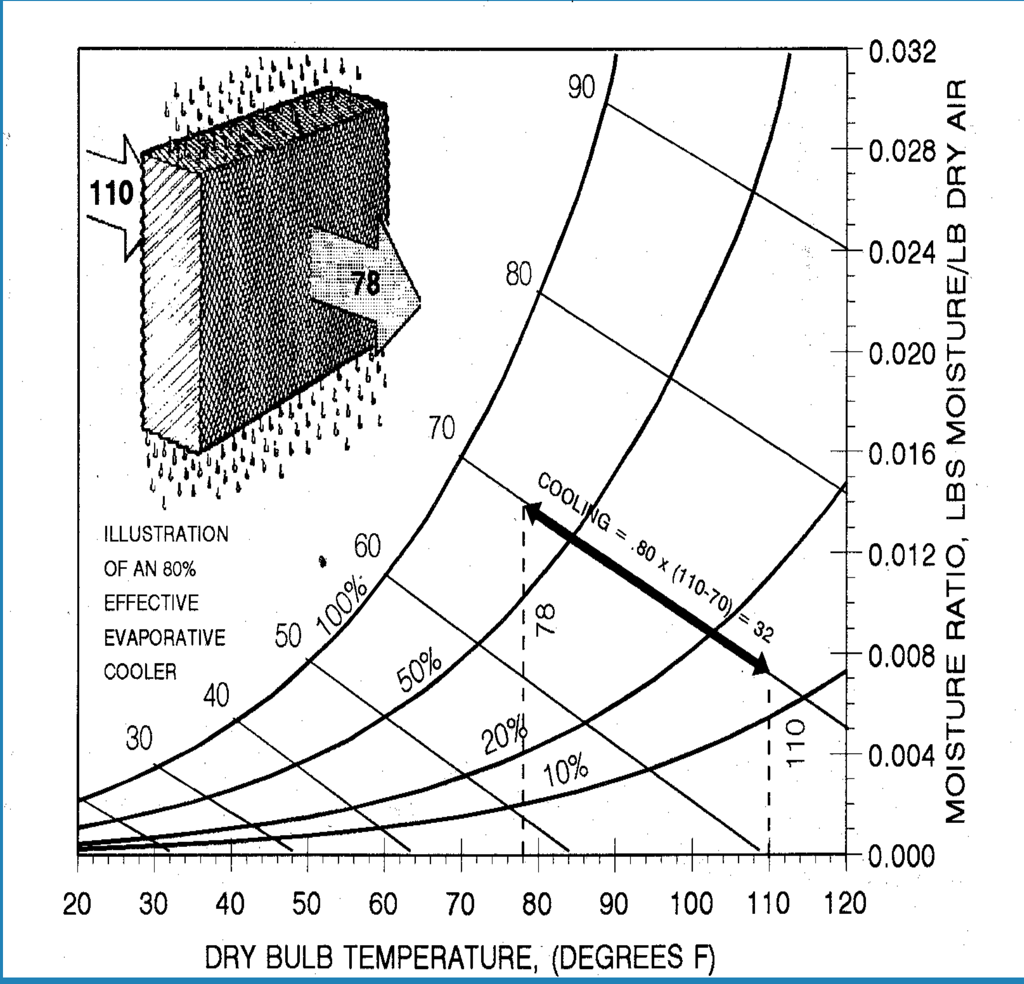
$$E = (TI_{db} - TD_{db}) \div (TI_{db} - TI_{wb})$$

"Discharge Temperature" can be determined by the following equation:

$$TD_{db} = TI_{db} - [E \times (TI_{db} - TI_{wb})]$$

Factors affecting effectiveness are:

- Type of Media
- Depth of Media
- Face Velocity



Evaporative Cooling:
Indirect Evaporative Cooling Cycle

"Effectiveness" is defined by the following equation:

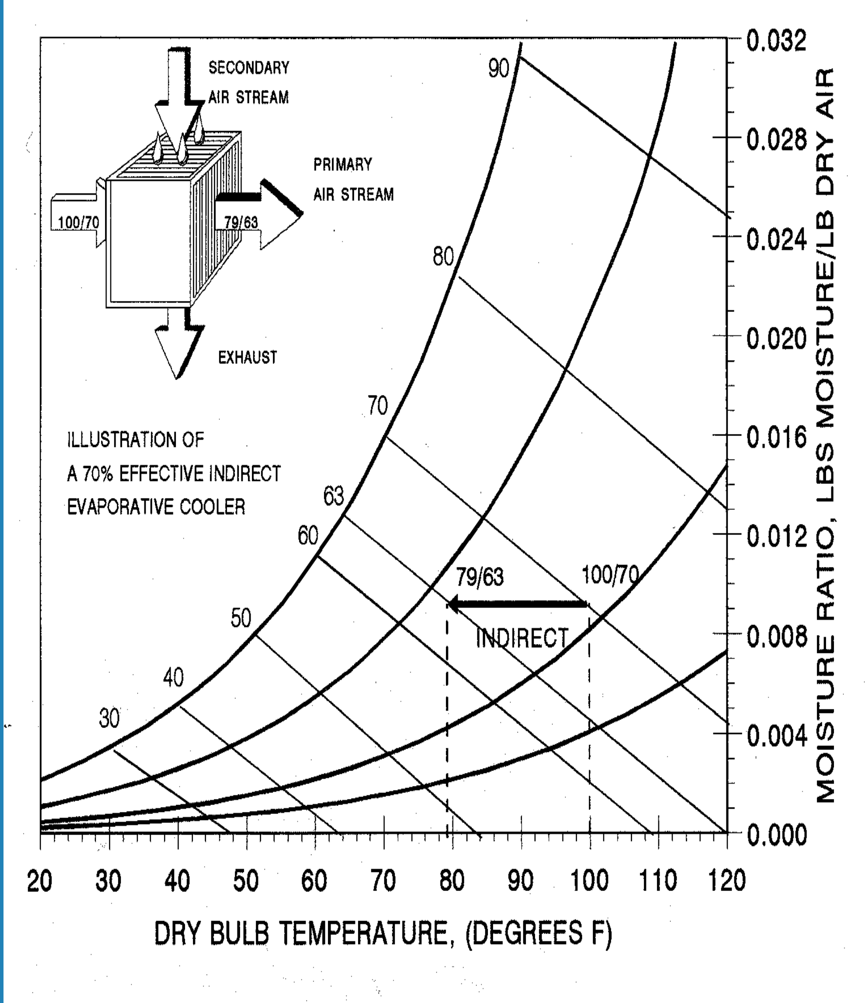
$$E = (TI_{db} - TD_{db}) \div (TI_{db} - TIS_{wb})$$

"Discharge Temperature" can be determined by the following equation:

$$TD_{db} = TI_{db} - [E \times (TI_{db} - TIS_{wb})]$$

Factors affecting effectiveness are:

- Type of Heat Exchanger
- Supply Air Flow Through Exchanger
- Secondary Air Flow
- Use of Outside Air vs. Building Exhaust as the Secondary Air Source



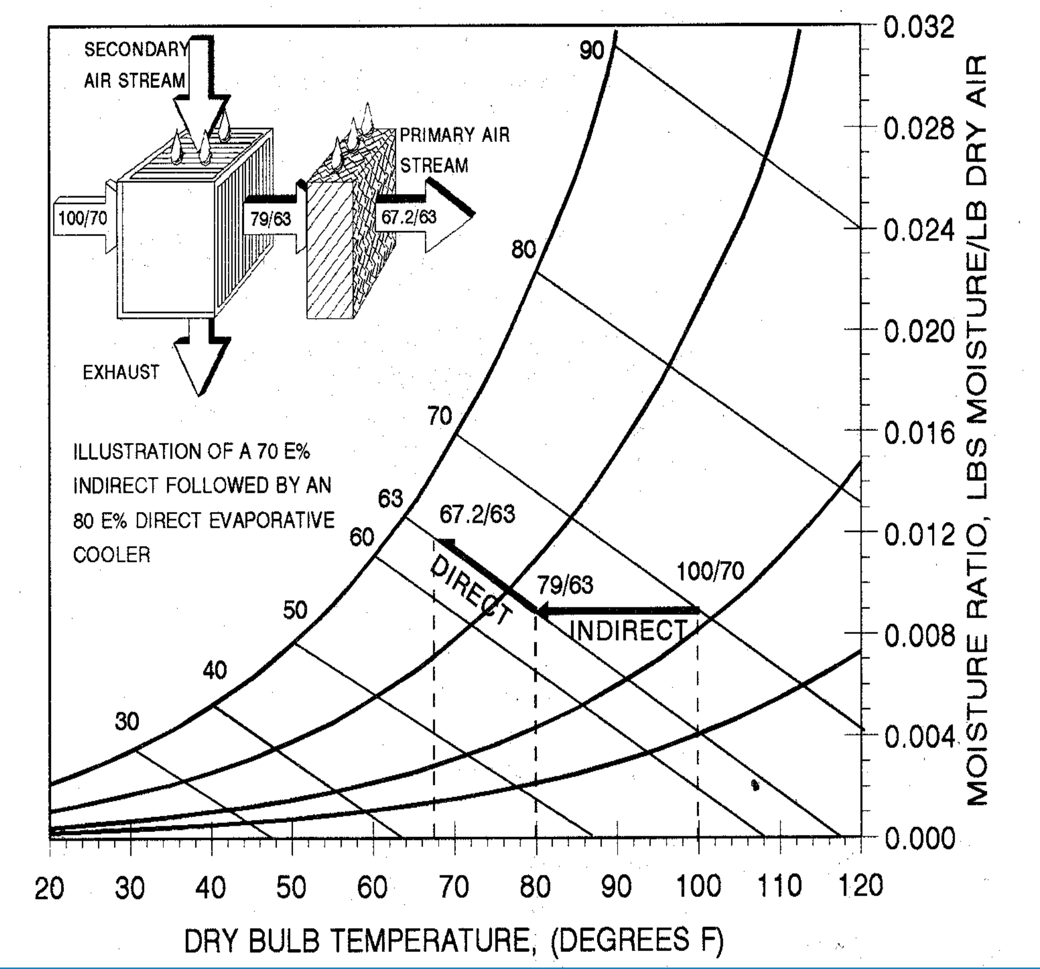
Evaporative Cooling:
Advantages of Indirect Cooling/Heating

- Provides a sensible cooling process
- Extends the effective Economizer range
- Meets base cooling loads under part load conditions most of the time
- Can be used to provide winter energy (heat) recovery
- Makes 100% outside air applications more economical than recirculation systems
- Reduces need for refrigeration

Evaporative Cooling:

Indirect/Direct Evaporative Cooling Cycle

- An Indirect / Direct combination will provide cooler air than either process by itself
- In certain climates this combined process alone will provide true "comfort cooling"



Evaporative Cooling:
Performance Chart (Low Wet Bulb Area)

SACRAMENTO, CALIFORNIA
Performance of Evaporative Cooling and Heat Recovery Technologies

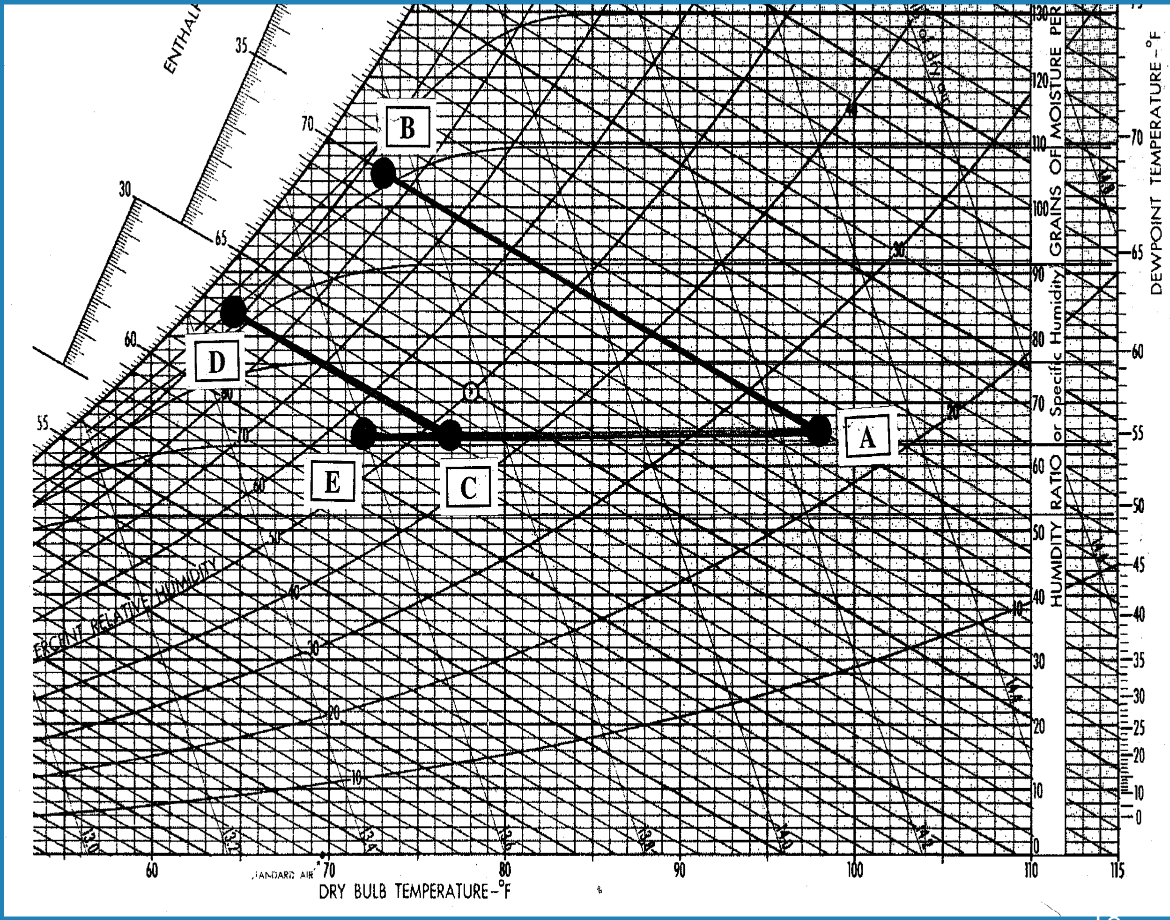
Ambient OSA DB/WB	Hours/ Year	INDIRECT OSA as Secondary Air	INDIRECT Bldg. Exhaust as Secondary Air	DIRECT	INDIRECT DIRECT OSA as Secondary Air
107/70	7	79/61	74/59	74/70	63/61
102/70	59	78/63	73/61	73/70	65/63
97/68	144	75/61	72/60	71/68	62/61
92/66	242	72/60	70/59	69/66	61/60
87/65	301	70/59	69/59	67/65	60/59
82/63	397	68/58	68/58	65/63	59/58
77/61	497	65/57	66/57	63/61	58/57
72/59	641	62/55	65/56	60/59	56/55
67/57	821	60/54	64/56	58/57	55/54
62/54	1086	56/52	63/55	55/54	53/52

The above discharge temperatures (^oF) are based on the following:

1. 75% Indirect Evaporative Effectiveness
2. 90% Direct Evaporative Effectiveness
3. 50% Heat Recovery Effectiveness
4. 75^{o}F Building Exhaust Dry Bulb Temperature (Heat Recovery)
5. 63^{o}F Building Exhaust Wet Bulb Temperature (Cooling)
6. DB = Dry Bulb Temperature
7. WB = Wet Bulb Temperature
8. OSA = Outside Air

Evaporative Cooling:
Psychrometric Chart (Low Wet Bulb)

- **Sacramento, CA**
- A: Outside air 98/70
- B: Direct 73/70
- C: Indirect (OSA) 77/63
- D: Indirect/Direct 64.5/63
- E: Indirect (bldg. exhaust) 72/62



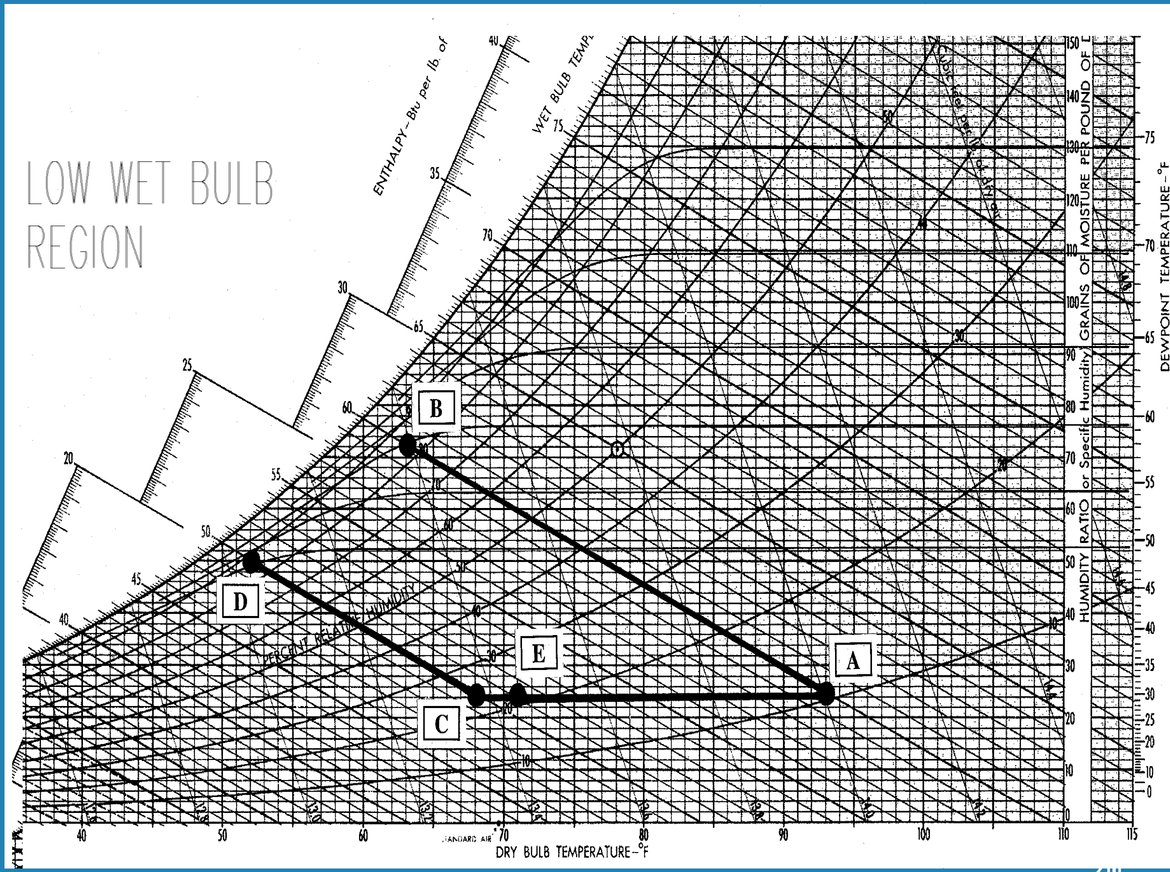
Evaporative Cooling:
Performance Chart (Low Wet Bulb Area)

RENO, NEVADA

Ambient OSA DB/WB	Hours/ Year	INDIRECT OSA as Secondary Air	IND/DIRECT OSA as Secondary Air	DIRECT	HEAT RECOVERY
97/60	18	69/50	52/50	64/60	
92/60	127	68/51	53/51	63/60	
87/58	297	65/50	52/50	61/58	
82/56	339	63/49	59/49	59/56	
77/55	390	61/49	50/49	57/55	
72/53	397	58/48	49/48	55/53	
67/50	436	54/45	46/45	52/50	
62/48	720	52/44	45/44	49/48	68.5
57/46	783	49/43	44/43	47/46	66
52/43	871				63.5
47/40	922				61
42/36	714				58.5
37/33	873				56
32/29	762				53.5
27/25	550				51
22/21	310				48.5
17/16	246				46
12/11	74				43.5
7/6	10				41
2	2				38.5
-2	3				36.5
-7	6				34

Evaporative Cooling:
Psychrometric Chart (Low Wet Bulb)

- **Reno, NV**
- A: Outside air 93/60
- B: Direct 63/60
- C: Indirect (OSA) 68/50
- D: Indirect/Direct 52/50
- E: Indirect (building exhaust) 71/51



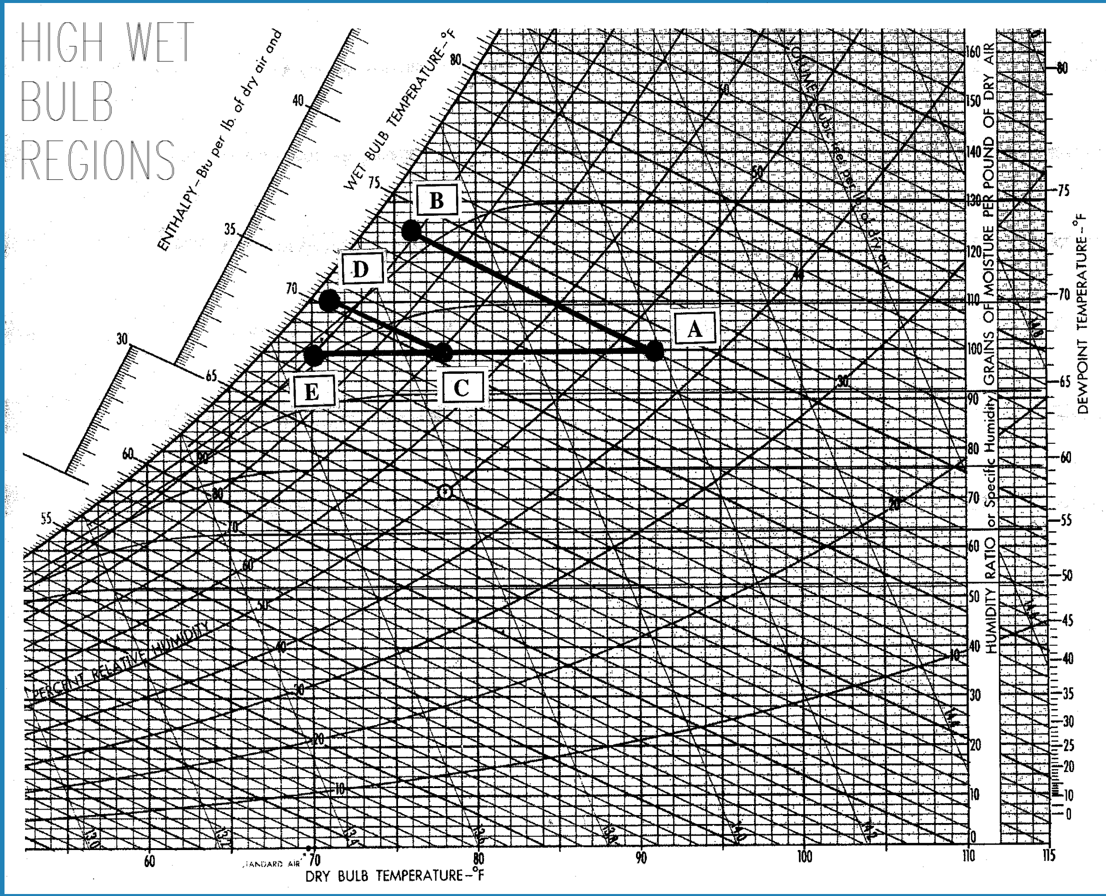
Evaporative Cooling:
Performance Chart (High Wet Bulb Area)

CHICAGO, ILLINOIS

Ambient OSA DB/WB	Hours/ Year	INDIRECT OSA as Secondary Air	INDIRECT Bldg. Exhaust as Secondary Air	DIRECT	INDIRECT DIRECT OSA as Secondary Air	HEAT RE-COVERY
97/76	6	81/71	71/69	78/76	72/71	
92/74	58	78/70	70/68	76/74	71/70	
87/72	165	76/69	69/67	73/72	70/69	
82/70	324	73/67	68/66	71/70	68/67	
77/67	487	70/65	67/64	68/67	66/65	
72/64	681	66/62	65/62	65/64	63/62	
67/61	759	62/59	64/60	62/61	60/58	
62/57	700	60/56		58/57	57/55	
57/52	604	53/50		53/52	51/49	
52/47	581					66
47/43	565					64
42/38	572					62
37/34	725					60
32/30	869					58
27/25	589					56
22/21	371					54
17/16	231					52
12/11	164					50
7/6	115					48
2/1	89					46
-3	53					44
-8	27					42
-13	11					40
-17	2					38

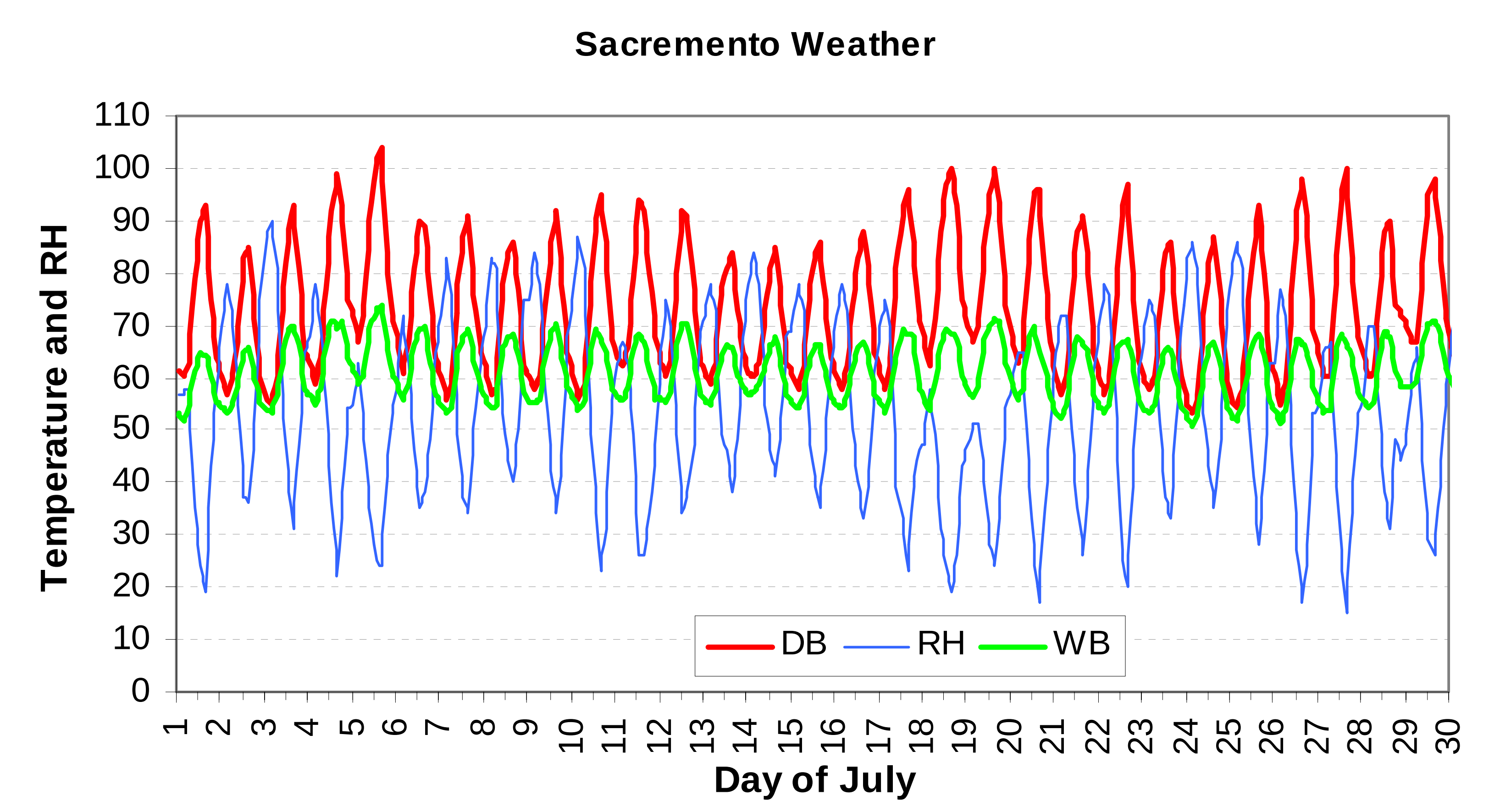
Evaporative Cooling:
Psychrometric Chart (High Wet Bulb)

- **Chicago, IL**
- A: Outside air 91/74
- B: Direct 76/74
- C: Indirect (OSA) 78/70
- D: Indirect/Direct 71/70
- E: Indirect (building exhaust) 70/68



Evaporative Cooling:

Dry Bulb, Wet Bulb and Relative Humidity Excursions



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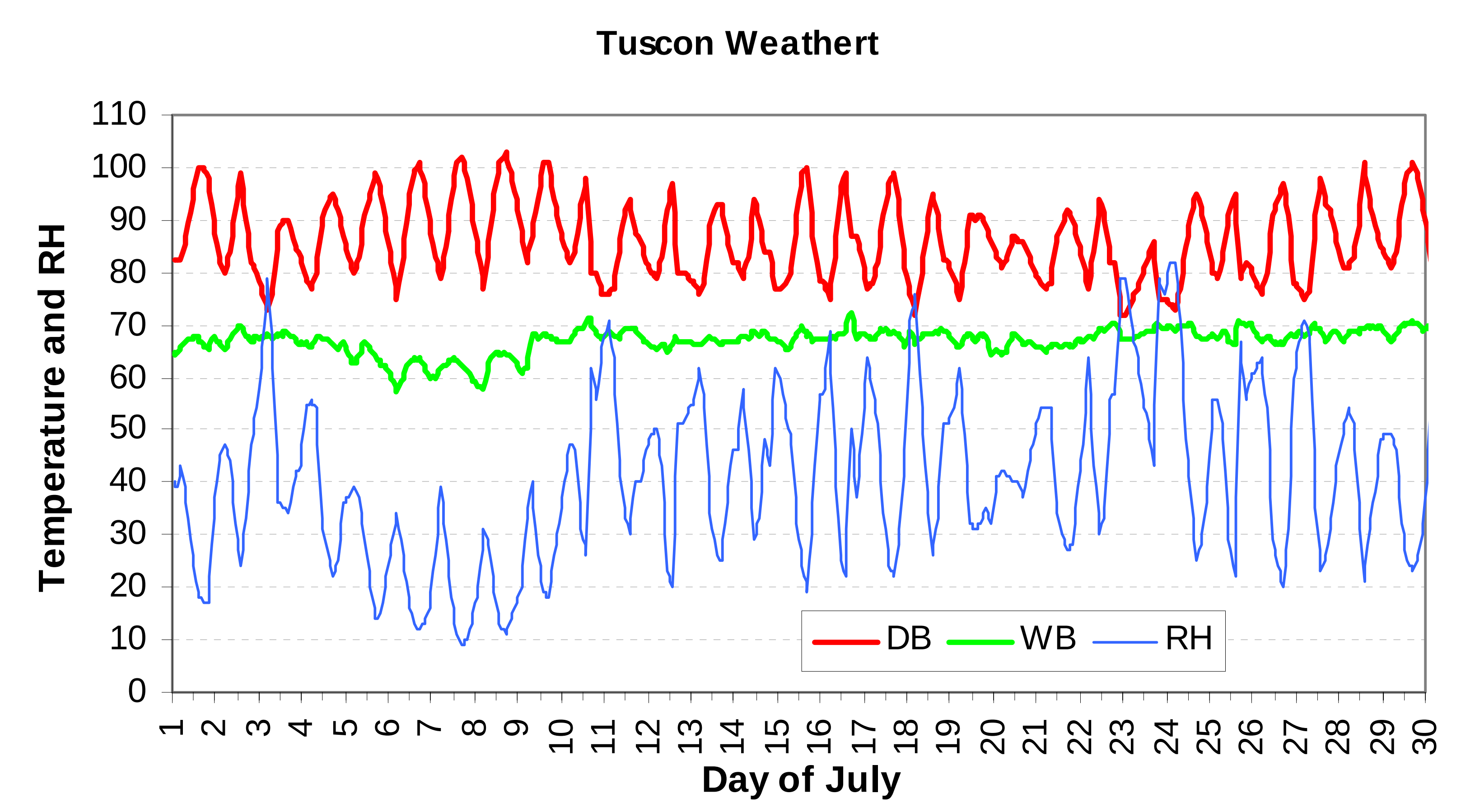

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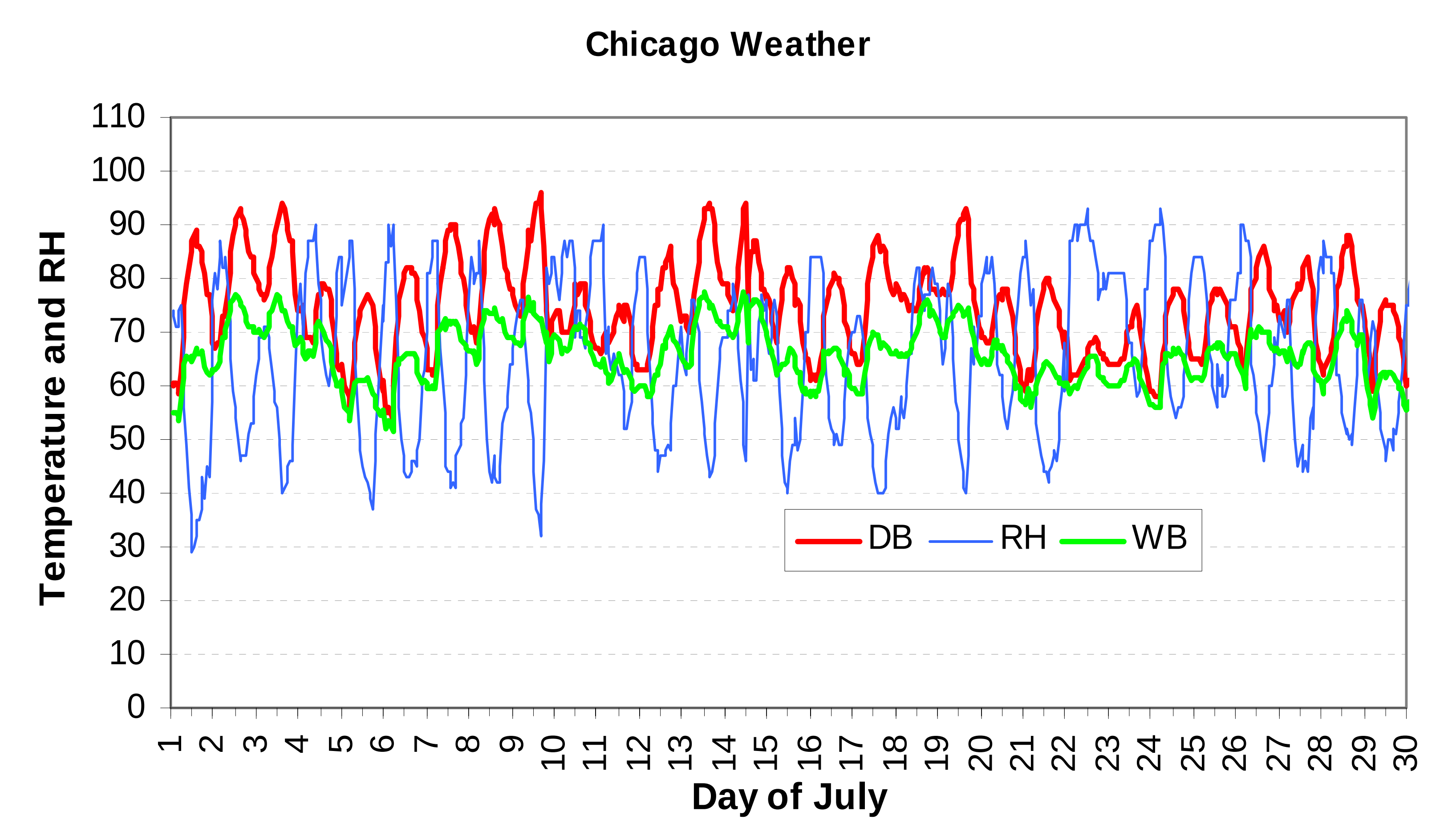
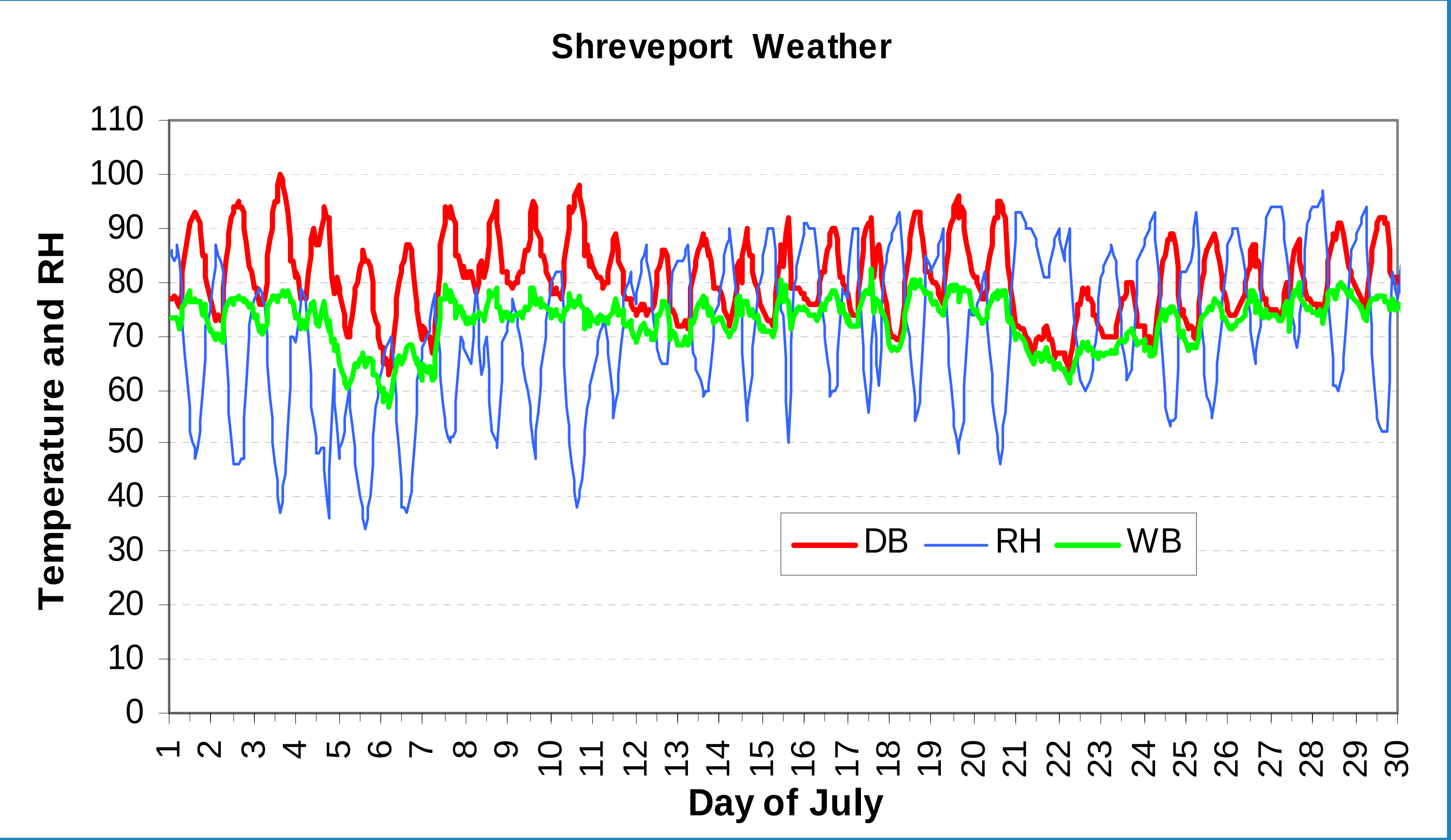
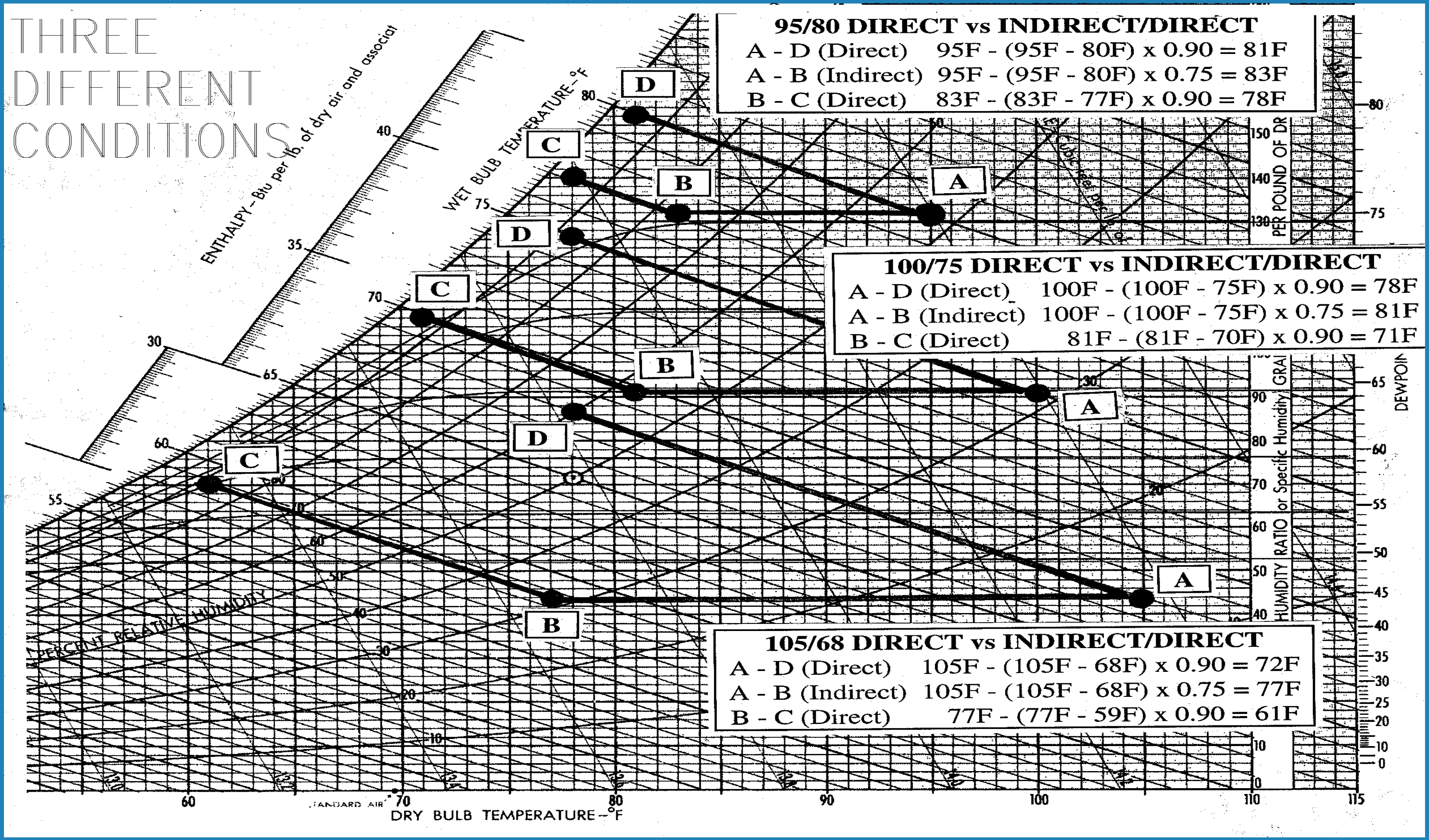


Evaporative Cooling:

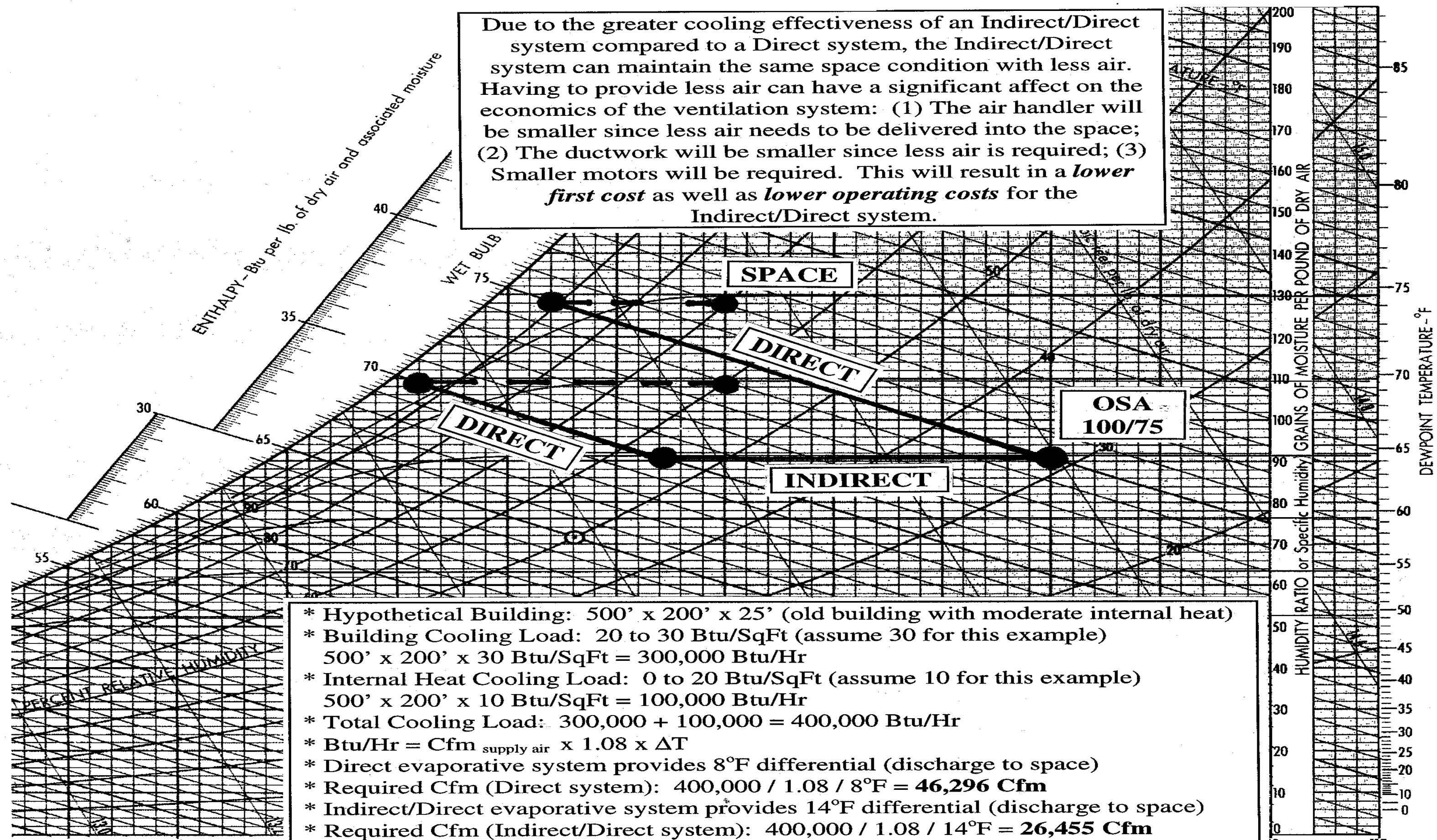
Dry Bulb, Wet Bulb and Relative Humidity Excursions



Evaporative Cooling:
3 Different Outside Air Conditions



Evaporative Cooling:
Comparison of Direct vs Indirect/Direct



Due to the greater cooling effectiveness of an Indirect/Direct system compared to a Direct system, the Indirect/Direct system can maintain the same space condition with less air. Having to provide less air can have a significant affect on the economics of the ventilation system: (1) The air handler will be smaller since less air needs to be delivered into the space; (2) The ductwork will be smaller since less air is required; (3) Smaller motors will be required. This will result in a ***lower first cost*** as well as ***lower operating costs*** for the Indirect/Direct system.

* Hypothetical Building: 500’ x 200’ x 25’ (old building with moderate internal heat)
* Building Cooling Load: 20 to 30 Btu/SqFt (assume 30 for this example)
  500’ x 200’ x 30 Btu/SqFt = 300,000 Btu/Hr
* Internal Heat Cooling Load: 0 to 20 Btu/SqFt (assume 10 for this example)
  500’ x 200’ x 10 Btu/SqFt = 100,000 Btu/Hr
* Total Cooling Load: 300,000 + 100,000 = 400,000 Btu/Hr
* Btu/Hr = $Cfm_{\text{supply air}}$ x 1.08 x ΔT
* Direct evaporative system provides 8°F differential (discharge to space)
* Required Cfm (Direct system): 400,000 / 1.08 / 8°F = **46,296 Cfm**
* Indirect/Direct evaporative system provides 14°F differential (discharge to space)
* Required Cfm (Indirect/Direct system): 400,000 / 1.08 / 14°F = **26,455 Cfm**
* Use of **Stratification** and **Spot Cooling** strategies will reduce the actual cooling load approximately in half
* Required Cfm (Direct system): 46,295 / 2 = **23,148 Cfm**
* Required Cfm (Indirect/Direct system): 26,455 / 2 = **13,227 Cfm**

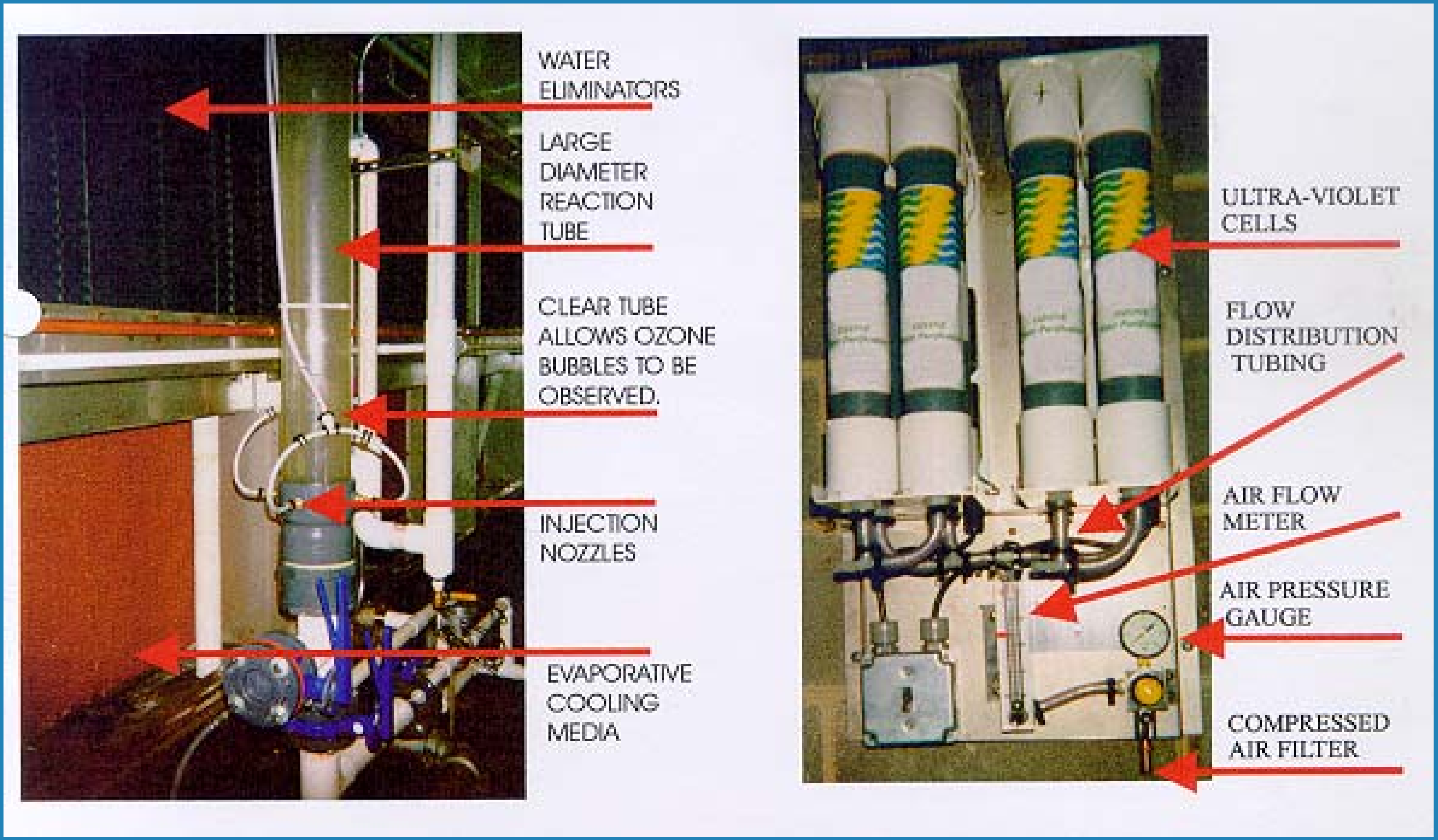
Evaporative Cooling:
Typical Direct Evaporative Module

- Design Features of a Good Evaporative System
  - Stainless Steel
  - Bottom Drain
  - Bleed and/or Purge
  - Pre-filters
  - Hood/Louvers
  - Mist Eliminators
  - Microbial Control
    - Dry the Pads
    - Run Fan After Pump Shuts Off
    - Flush Pads
    - Ozonation

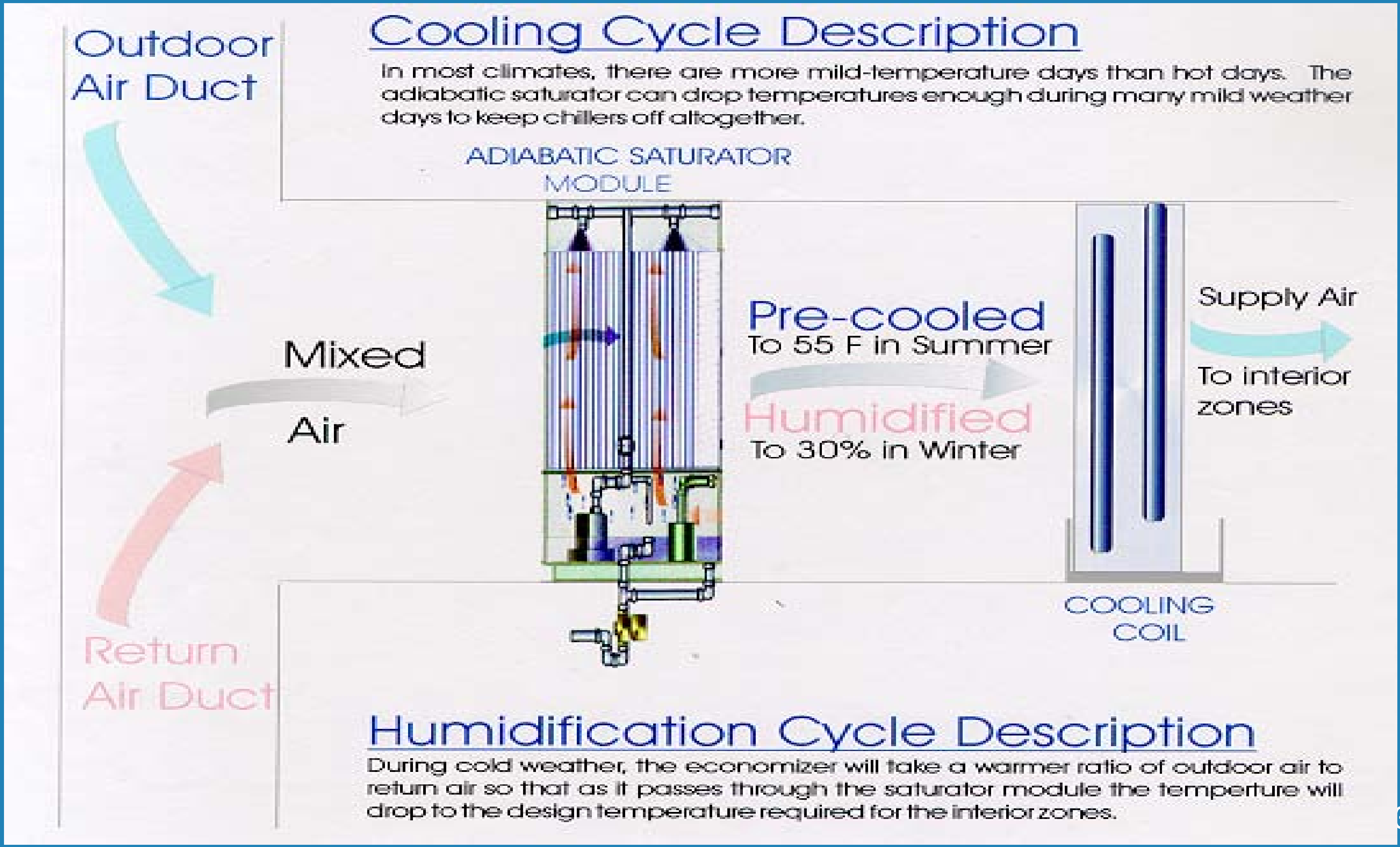
Evaporative Cooling
Microbial Control

- There have been no cases of Legionnaire's Disease associated with evaporative coolers (see ASHRAE Guideline 12-2000)
- There are significant differences between evaporative coolers and cooling towers
- The ***Bio-Terminator***™ ozonation system was designed for active microbial control
- Ozone (O_3) is an extremely powerful oxidizer
  - Highly soluble in water
  - Very short half life
  - Benign at low levels

Evaporative Cooling:
Microbial Control



Evaporative Cooling:
Cooling And Humidification



Evaporative Cooling:
What Are The Adverse Affects Of Heat?

- Industrial facilities are particularly susceptible to problems related to heat during extended periods of the year.
  - Heat stress
  - Increased down time
  - Quality control problems
  - Reduced productivity
- Many companies have done internal studies on the true costs of such heat related problems…the results are discouraging and most often not made public!

Evaporative Cooling:
What Are The Adverse Affects Of Heat?

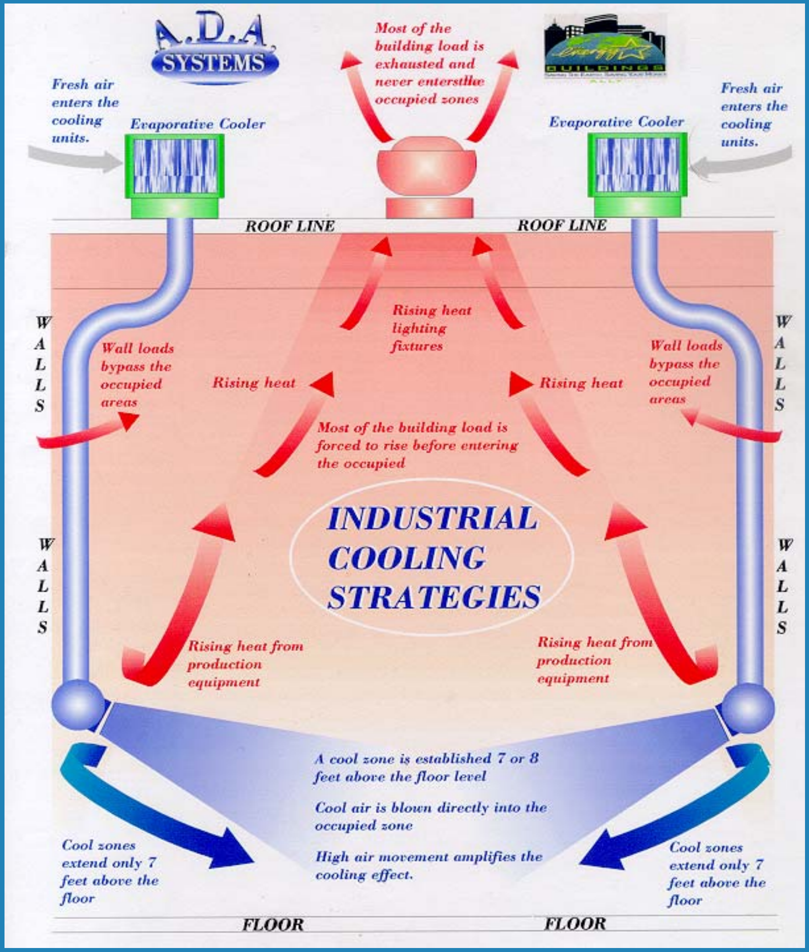
NASA Report CR-1205-1 (Heat Stress)

Effective Temperature	75	80	85	90	95	100	105
Loss in Work Output	3%	8%	18%	29%	45%	62%	79%
Loss in Accuracy	-	5%	40%	300%	700%	-	-

- ACGIH has established guidelines for reducing heat stress, including:
  - Increased rates of ventilation
  - Evaporative cooling of ventilation air
  - Displacement ventilation with stratification
  - Increased fluid intake

Evaporative Cooling:
Industrial Cooling Strategies

- Strategies to increase the effectiveness of evaporative cooling:
  - Displacement Ventilation
  - Stratification
  - Spot Cooling
  - Adjustable Diffusers



Evaporative Cooling:
Indirect/Direct Case Study No. 1

CLIENT: Indianapolis Wood Veneer Manufacturer

PROBLEM: Ovens Produce Over 100ºF Conditions

GOAL: Low Cost Relief Cooling

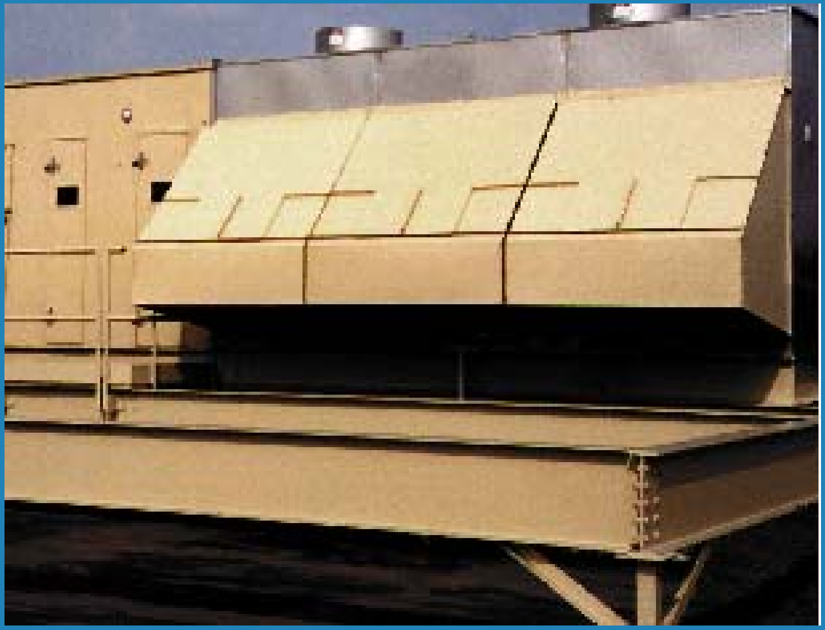
SOLUTION:

* Indirect/ Direct Cooling System

* Stratification Strategy

* Spot Cooling

***Eliminates The Previously Proposed 1,880-Ton Chilled Water System**



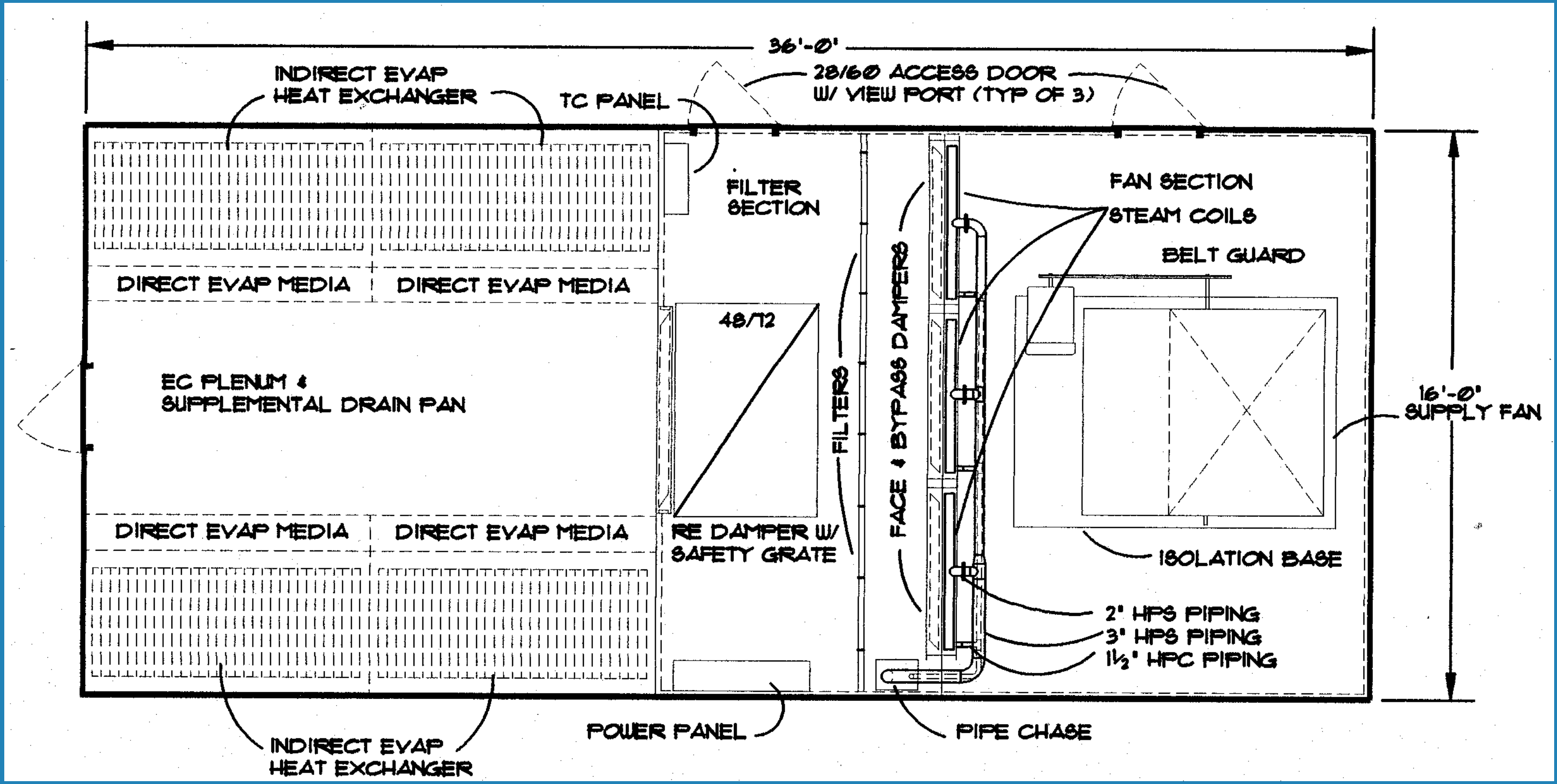
Evaporative Cooling:
Indirect/Direct Case Study No. 1

EQUIPMENT SCHEDULE

Mark	Manu-facturer	Supply Cfm	E.A.T (O.S.A) (°FDB)	E.A.T (O.S.A) (°FWB)	L.A.T. Indirect (°FDB)	L.A.T. Indirect (°FWB)	L.A.T. Direct (°FDB)	Efficiency (Indirect) (%)	Efficiency (Direct) (%)
AHU-1		62,000	91.0	75.0	78.0	71.5	72.3	80	88
AHU-2		62,000	91.0	75.0	78.0	71.5	72.3	80	88
AHU-3		62,000	91.0	75.0	78.0	71.5	72.3	80	88
AHU-4		25,000	91.0	75.0	78.0	71.5	72.2	80	90

Evaporative Cooling: Indirect/Direct Case Study No. 1

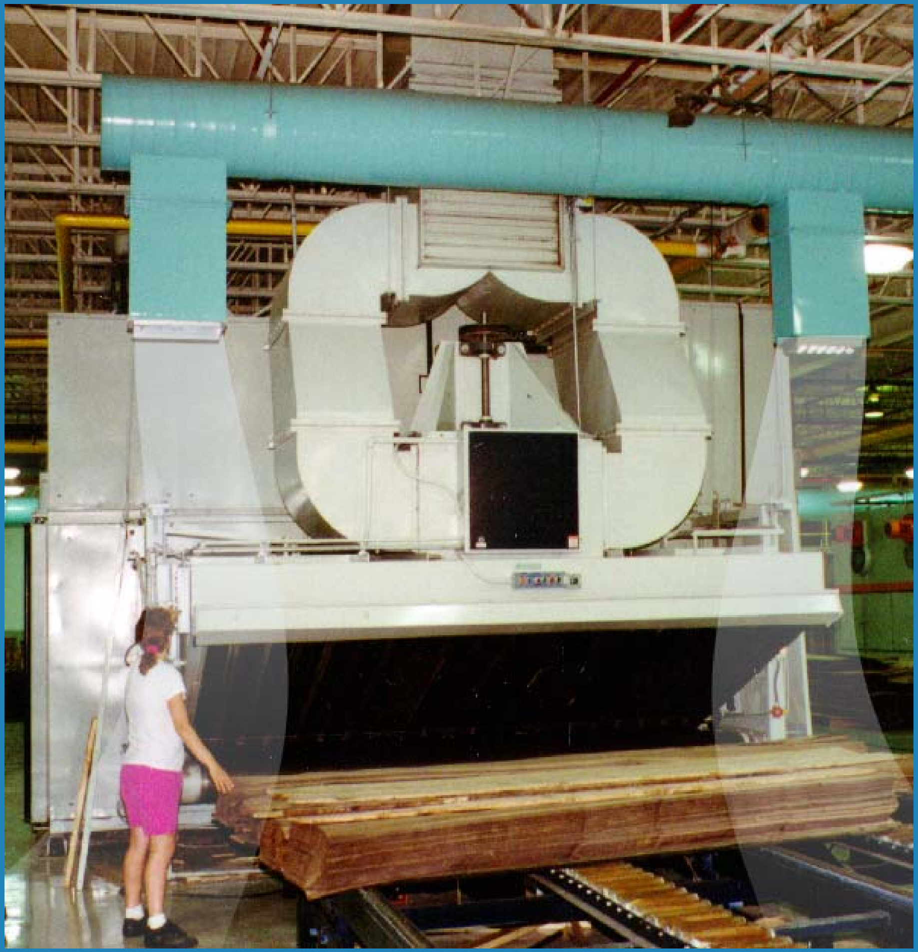
62,000 CFM Make Up Air Handling Unit



Evaporative Cooling:
Indirect/Direct Case Study No. 1

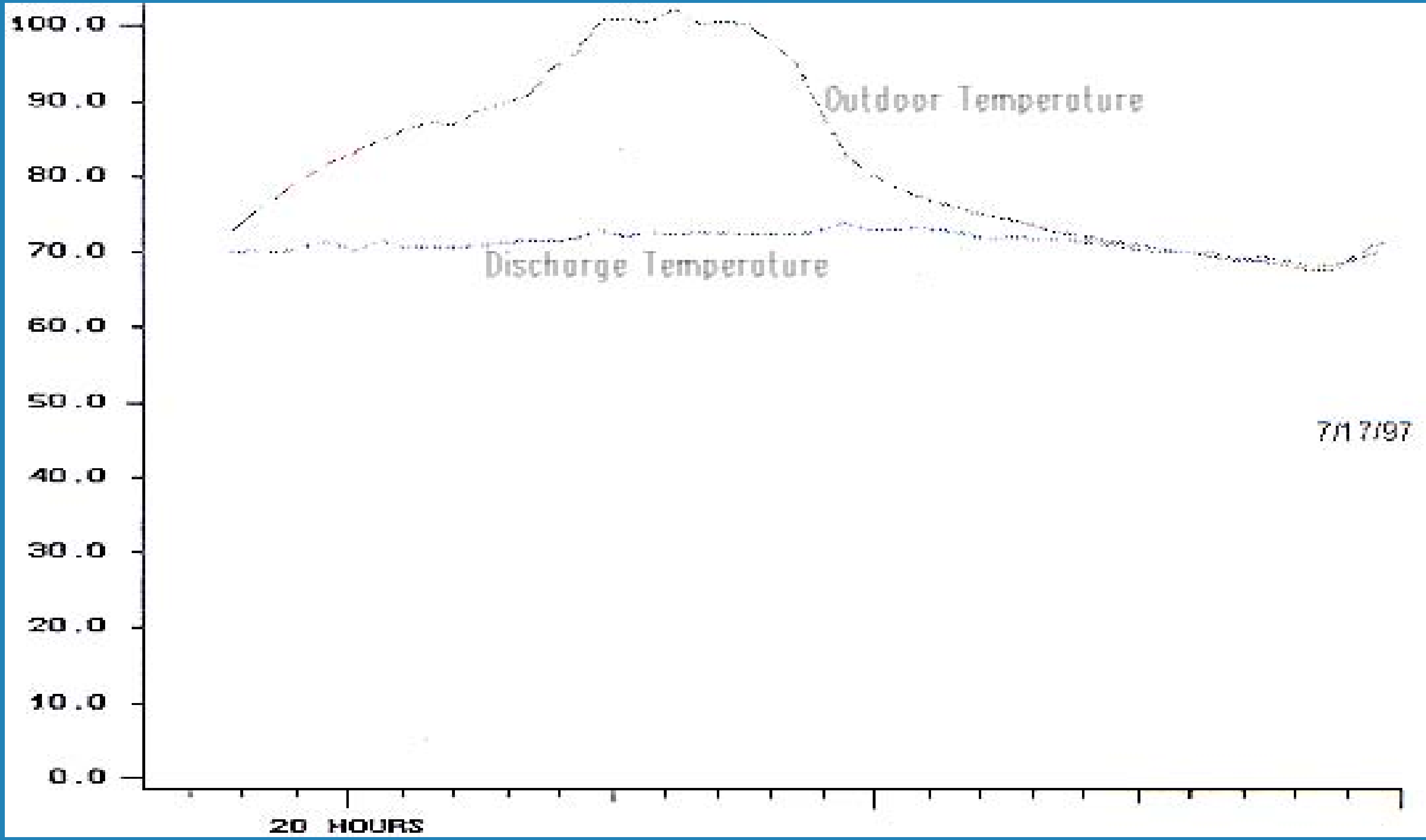
SPOT COOLING

* Adjustable Diffusers
* High Air Movement
* Establishes Cool Zone



Evaporative Cooling:
Indirect/Direct Case Study No. 1

Field Temperature Recording



Evaporative Cooling:
Indirect With Chiller & Heat Recovery

- An Indirect evaporative pre-cooler can be used to reduce the size of a new chilled water system, or can be used to reduce the outside air load on an existing system.
- When used for energy (heat) recovery in winter operations, that same indirect unit can pre-heat the outside air.
  - In certain parts of the country, the energy savings from heat recovery may be even greater than those from evaporative cooling

Evaporative Cooling:
Indirect Case Study No. 2

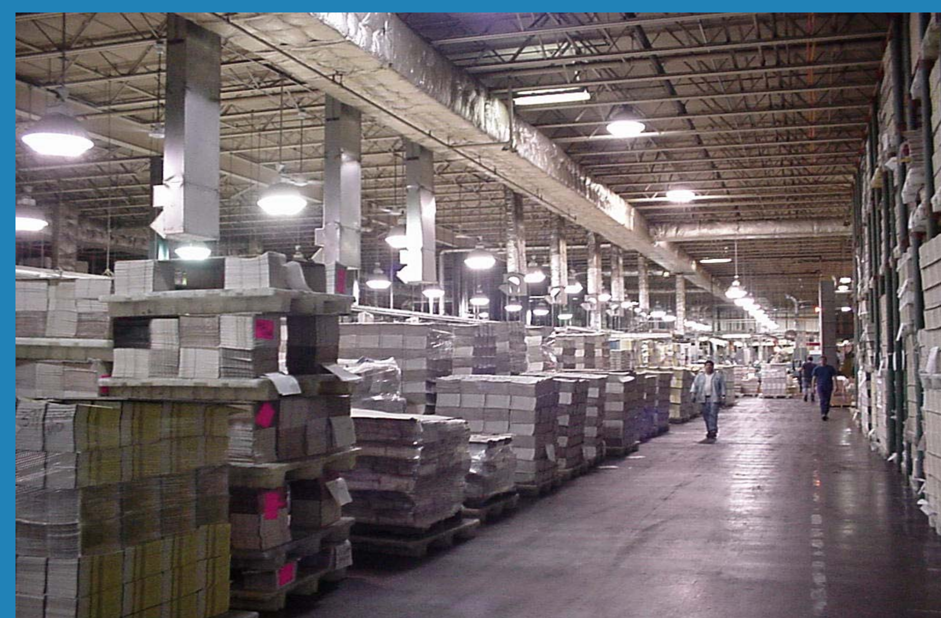
- CLIENT: Midwest Printing Facility
- PROBLEM: Inability Of Chilled Water System To Maintain Space Conditions
- GOAL: Avoid Increasing The Chilled Water Plant

*SOLUTION:

*Indirect Precooling

*Eliminates The Need To Double The Size Of The Chilled Water System

*Regains The Desired Space Conditions



Evaporative Cooling:
Indirect Case Study No. 2

*BEFORE: 18,000 CFM Outside Air Hood

*AFTER: 18,000 CFM Indirect Evaporative Pre-Cooler

Evaporative Cooling:
Indirect With Chiller & Heat Recovery
Case Study No. 3

- CLIENT: Midwest Automotive Facility
- GOAL: Achieve **LEED**™ Certification In An Industrial Facility
- PROBLEM: How To Achieve Meaningful Energy Cost Reductions And Still Maintain Good IAQ/IEQ
- SOLUTION: Indirect Evaporative Pre-Cooling and Pre-Heating
  - **Reduces Chilled Water Plant By ~42%**
  - **Reduces Heating Plant By~60%**

Evaporative Cooling:
Indirect With Chiller & Heat Recovery
(30% Outdoor Air Unit) (Industrial Facility)

IDEC COOLING PERFORMANCE (24-7 operating hours) (ADA SYSTEMS - 425 North Gary Ave
Carol Stream, IL 60188 / Ph: 630-871-2500

JOB: **************- Lansing, , MI

THIRTY (30) - 30% OUTDOOR AIR UNITS

***30% Outdoor Air Unit**

LOCATION	LANSING	MI	
EER SEASONAL AVERAGE	**41.6**	Btu/watt	Enthalpy
SUPPLY AIR TEMP	57.7	56.5 24.7	
EXHAUST	59.7	57.5	
HOURS OF COOLING OPERATION	3180		
IDEC SIZE	16	Linear Ft	2,470
IDEC PRIMARY and SECONDARY CFM	15,000	Each	
IDEC ENERGY DRAW (kW/hr) - ON	4,940	watts	308.73 4,940
IDEC ENERGY DRAW (watts/hr) - OFF	2,470	watts	102.91 watts/ft of module
IDEC EQUIPMENT COST (uninstalled)	$ 33,750	per air handling unit	
IDEC EQUIPMENT COST (uninstalled)	$ 2.25	per CFM	
IDEC EQUIPMENT COST (per ton uninstalled)	$ 974	per ton cooling	
Water Chiller/cooling tower/pumps/piping (unistalled)	$ 700	per ton cooling	
Premium for IDEC equipment over chilled water equipment	$ 9,500	per air handling unit	
IDEC TONS delivered at design conditions	35	Tons	Also Tons of Chiller size reduction
CHILLER TONS required at design conditions	48	Tons	
TOTAL COOLING TONS (IDEC + Chiller)	83	Tons	dedicated to OA load
IDEC Efficiency	80%	efficiency	
Kw/hr Cost	$ 0.08	Kw/hr	
Water Cost (per 1000 gallons)	$ 2.50	per 1000 gallons	
IDEC Yearly energy costs	$ 1,576	per air handling unit	
CHILLER equivalent yearly energy costs	$ 6,555	per air handling unit	
YEARLY COOLING SEASON SAVINGS	**$ 5,000**	per air handling unit	

PRIMARY Air Entering DB (F)	WB (F)	H Btu/lb	SECONDARY Air entering DB (F)	WB (F)	H Btu/lb	PRIMARY Air leaving DB (F)	WB (F)	H Btu/lb	IDEC Btu/ Lb Drop
97	76	39.38	75	64	29.30	70.6	68.0	33.22	6.2
92	74	37.50	75	64	29.30	69.6	67.5	32.81	4.7
87	72	35.71	75	64	29.30	68.6	66.5	31.99	3.71975
82	70	33.99	75	64	29.30	67.6	65.0	30.80	3.2
77	67	31.54	75	64	29.30	66.6	63.2	29.42	2.1
72	64	29.25	75	64	29.30	65.6	61.8	28.38	0.9
67	61	27.11	67	61	29.30	62.2	59.2	26.55	0.6
62	57	24.44	62	57	29.30	58.0	55.2	23.91	0.5

PRIMARY Air Entering DB (F)	IDEC Out Btu/hr Drop	IDEC Input Watts/ Hr	**EER Btu Per Watt**	HRS Total Yearly BIN	ENERGY Output for each BIN	ENERGY BIN% of Total Output	EER Contri- bution /BIN	ENERGY Input for Each /BIN	COST Energy Input IDEC	GALS Water Consu- mption	COST Water Consu- mption	OPER- ATING Cost TOTAL
97	4.2E+05	4,939.7	**84**	6	2.5E+06	1%	1	3.0E+04	$ 2	375	$ 1	$ 3
92	3.2E+05	4,939.7	**64**	58	1.8E+07	6%	4	2.9E+05	$ 23	3,375	$ 8	$ 31
87	2.5E+05	4,939.7	**51**	165	4.1E+07	14%	7	8.2E+05	$ 65	7,875	$ 20	$ 85
82	2.2E+05	4,939.7	**44**	324	7.0E+07	24%	10	1.6E+06	$ 128	12,000	$ 30	$ 158
77	1.4E+05	4,939.7	**29**	487	7.0E+07	24%	7	2.4E+06	$ 192	13,500	$ 34	$ 226
72	5.9E+04	4,939.7	**12**	681	4.0E+07	14%	2	3.4E+06	$ 269	12,000	$ 30	$ 299
67	3.8E+04	4,939.7	**8**	759	2.9E+07	10%	1	3.7E+06	$ 300	8,625	$ 22	$ 321
62	3.6E+04	4,939.7	**7**	700	2.5E+07	8%	1	3.5E+06	$ 277	6,075	$ 15	$ 292
			42	3180	3.0E+08	100%	32	1.6E+07	$ 1,257	63,825	$ 160	$ 1,416

Evaporative Cooling:
Indirect With Chiller & Heat Recovery
(30% Outdoor Air Unit) (Industrial Facility)

IDEC HEATING PERFORMANCE (24/7 operating hours)

(ADA SYSTEMS - 425 North Gary Ave
Carol Stream, IL 60188 / Ph: 630-871-2500

JOB: ************- Lansing, MI**

THIRTY(30) - 30% OUTDOOR AIR UNITS

LOCATION		LANSING
TOTAL HOURS OPERATION (24 hour /7 day)		5568
IDEC SIZE		16 FT
IDEC PRIMARY and SECONDARY CFM		15,000 Each
IDEC ENERGY DRAW (Kw/hr) - pumps off		4,940
IDEC EQUIPMENT COST (per CFM)	$	2.25
IDEC EFFICIENCY (dry)		65%
Kw/hr Cost	$	0.08
NatGas (per Therm)	$	0.75
Assumed Furnace Efficiency		100%
YEARLY HEATING SEASON SAVINGS	**$**	**12,700**

SUMMARY		
Yearly Heating Savings	$	12,700
Yearly Cooling Savings	$	5,000
TOTAL Yearly Savings	$	17,700
IDEC Premium	$	9,500
PAYBACK - Years		**0.54**

***30% Outdoor Air Unit**

SUPPLY AIR ENTERING (F)	EXHAUST AIR ENTERING (F)	HOURS PER YEAR (Hrs)	SUPPLY AIR LEAVING (F)	EXHAUST AIR LEAVING (F)	BTU/HR RECOV-ERED (Btu/hr)	BTU/BIN RECOV-ERED (Btu/bin)	THERMS PER BIN /Furn Eff	SAVINGS PER BIN	PARA-SIDICAL LOSS (Kw)	PARA-SIDICAL LOSS ($)	NET SAV-INGS ($)
57	70	604	65	62	1.4E+05	8.31E+07	831	$ 623	2,984	$ 239	$ 384
52	70	581	64	58	1.9E+05	1.11E+08	1,106	$ 830	2,870	$ 230	$ 600
47	70	565	62	55	2.4E+05	1.37E+08	1,375	$ 1,031	2,791	$ 223	$ 808
42	70	572	60	52	3.0E+05	1.69E+08	1,694	$ 1,271	2,825	$ 226	$ 1,045
37	70	725	58	49	3.5E+05	2.53E+08	2,531	$ 1,898	3,581	$ 287	$ 1,612
32	70	869	57	45	4.0E+05	3.49E+08	3,493	$ 2,620	4,293	$ 343	$ 2,277
27	70	589	55	42	4.5E+05	2.68E+08	2,679	$ 2,009	2,909	$ 233	$ 1,777
22	70	371	53	39	5.1E+05	1.88E+08	1,884	$ 1,413	1,833	$ 147	$ 1,266
17	70	231	51	36	5.6E+05	1.30E+08	1,295	$ 971	1,141	$ 91	$ 880
12	70	164	50	32	6.1E+05	1.01E+08	1,006	$ 755	810	$ 65	$ 690
7	70	115	48	34	6.7E+05	7.67E+07	767	$ 576	568	$ 45	$ 530
2	70	89	43	34	6.7E+05	5.94E+07	594	$ 445	440	$ 35	$ 410
-3	70	53	38	34	6.7E+05	3.54E+07	354	$ 265	262	$ 21	$ 244
-8	70	27	33	34	6.7E+05	1.80E+07	180	$ 135	133	$ 11	$ 124
-13	70	11	28	34	6.7E+05	7.34E+06	73	$ 55	54	$ 4	$ 51
-17	70	2	24	34	6.7E+05	1.33E+06	13	$ 10	10	$ 1	$ 9

Evaporative Cooling:
Indirect With Chiller & Heat Recovery
(100% Outdoor Air Unit) (Industrial Facility)

IDEC COOLING PERFORMANCE (24-7 operating hours) (ADA SYSTEMS - 425 North Gary Ave
Carol Stream, IL 60188 / Ph: 630-871-2500

JOB: ************- **Lansing, MI**

SEVEN(7) - ALL OUTDOOR AIR UNITS

LOCATION	LANSING		discharge
EER SEASONAL AVERAGE	**44.9**	Btu/watt	Enthalpy
SUPPLY AIR TEMP	62	61.0	27.3
EXHAUST	70	57.5	
HOURS OF COOLING OPERATION	3180		
IDEC SIZE	48	Linear Ft	2,470
IDEC PRIMARY and SECONDARY CFM	50,000	Each	
IDEC ENERGY DRAW (kW/hr) - ON	14,819	watts	308.73 1481899%
IDEC ENERGY DRAW (watts/hr) - OFF	7,409	watts	102.91 watts/ft of module
IDEC EQUIPMENT COST (uninstalled)	$ 112,500	per air handling unit	
IDEC EQUIPMENT COST (uninstalled)	$ 2.25	per CFM	
IDEC EQUIPMENT COST (per ton uninstalled)	$ 1,158	per ton cooling	
Water Chiller/cooling tower/pumps/piping (unistalled)	$ 700	per ton cooling	
Premium for IDEC equipment over chilled water equipment	$ 44,500	per air handling unit	
IDEC TONS delivered at design conditions	97	Tons	Also Tons of Chiller size reduction
CHILLER TONS required at design conditions	129	Tons	
TOTAL COOLING TONS (IDEC + Chiller)	227	Tons	
IDEC Efficiency	80%	efficiency	
Kw/hr Cost	$ 0.08	Kw/hr	
Water Cost (per 1000 gallons)	$ 2.50	per 1000 gallons	
IDEC Yearly energy costs	$ 4,834	per air handling unit	
CHILLER equivalent yearly energy costs	$ 21,722	per air handling unit	
YEARLY COOLING SEASON SAVINGS	**$ 16,900**	per air handling unit	

*100% Outdoor Air Unit

PRIMARY Air Entering			SECONDARY Air entering			PRIMARY Air leaving			IDEC	IDEC	IDEC	**EER**	HRS	ENERGY	ENERGY	EER	ENERGY	COST	GALS	COST	OPER-
DB (F)	WB (F)	H Btu/lb	DB (F)	WB (F)	H Btu/lb	DB (F)	WB (F)	H Btu/lb	Btu/ Lb Drop	Out Btu/hr Drop	Input Watts/ Hr	**Btu Per Watt**	Total Yearly BIN	Output for each BIN	BIN% of Total Output	Contri- bution /BIN	Input for Each /BIN	Energy Input IDEC	Water Consu- mption	Water Consu- mption	ATING Cost TOTAL
97	76	39.38	75	66	30.65	72.2	68.5	34.20	5.2	1.2E+06	14,819.0	**79**	6	7.0E+06	1%	1	8.9E+04	$ 7	1,250	$ 3	$ 10
92	74	37.50	75	66	30.65	71.2	68.0	32.20	5.3	1.2E+06	14,819.0	**80**	58	6.9E+07	8%	6	8.6E+05	$ 69	11,250	$ 28	$ 97
87	72	35.71	75	66	30.65	70.2	67.0	31.60	4.11	9.2E+05	14,819.0	**62**	165	1.5E+08	17%	11	2.4E+06	$ 196	26,250	$ 66	$ 261
82	70	33.99	75	66	30.65	69.2	65.5	30.80	3.2	7.2E+05	14,819.0	**48**	324	2.3E+08	26%	12	4.8E+06	$ 384	40,000	$ 100	$ 484
77	67	31.54	75	66	30.65	68.2	63.7	29.62	1.9	4.3E+05	14,819.0	**29**	487	2.1E+08	23%	7	7.2E+06	$ 577	45,000	$ 113	$ 690
72	64	29.25	75	66	30.65	67.2	62.3	28.58	0.7	1.5E+05	14,819.0	**10**	681	1.0E+08	11%	1	1.0E+07	$ 807	40,000	$ 100	$ 907
67	61	27.11	67	61	30.65	62.2	59.7	26.76	0.3	7.9E+04	14,819.0	**5**	759	6.0E+07	7%	0	1.1E+07	$ 900	28,750	$ 72	$ 972
62	57	24.44	62	57	30.65	58.0	55.7	24.01	0.4	9.7E+04	14,819.0	**7**	700	6.8E+07	8%	0	1.0E+07	$ 830	20,250	$ 51	$ 880
												45	3180	9.0E+08	100%	39	4.7E+07	$ 3,770	212,750	$ 532	$ 4,302

Evaporative Cooling:

Indirect With Chiller & Heat Recovery

(100% Outdoor Air Unit) (Industrial Facility)

IDEC HEATING PERFORMANCE (24/7 operating hours)

(ADA SYSTEMS - 425 North Gary Ave
Carol Stream, IL 60188 / Ph: 630-871-2500

JOB: ************- **Lansing, MI**

SEVEN(7) - ALL OUTDOOR AIR UNITS

LOCATION	LANSING	
TOTAL HOURS OPERATION (24 hour /7 day)	5568	
IDEC SIZE	48 Ft	
IDEC PRIMARY and SECONDARY CFM	50,000	Each
IDEC ENERGY DRAW (Kw/hr) - pumps off	14,819.0	
IDEC EQUIPMENT COST (per CFM)	$ 2.25	
IDEC EFFIENCY (dry)	65%	
Kw/hr Cost	$ 0.08	
NatGas (per Therm)	$ 0.75	
Assumed Furnace Efficiency	100%	
YEARLY HEATING SEASON SAVINGS	**$ 43,100**	

SUMMARY	
Yearly Heating Savings	$ 43,100
Yearly Cooling Savings	$ 16,900
TOTAL Yearly Savings	$ 60,000
IDEC Premium	$ 44,500
PAYBACK - Years	**0.74**

*100% Outdoor Air Unit

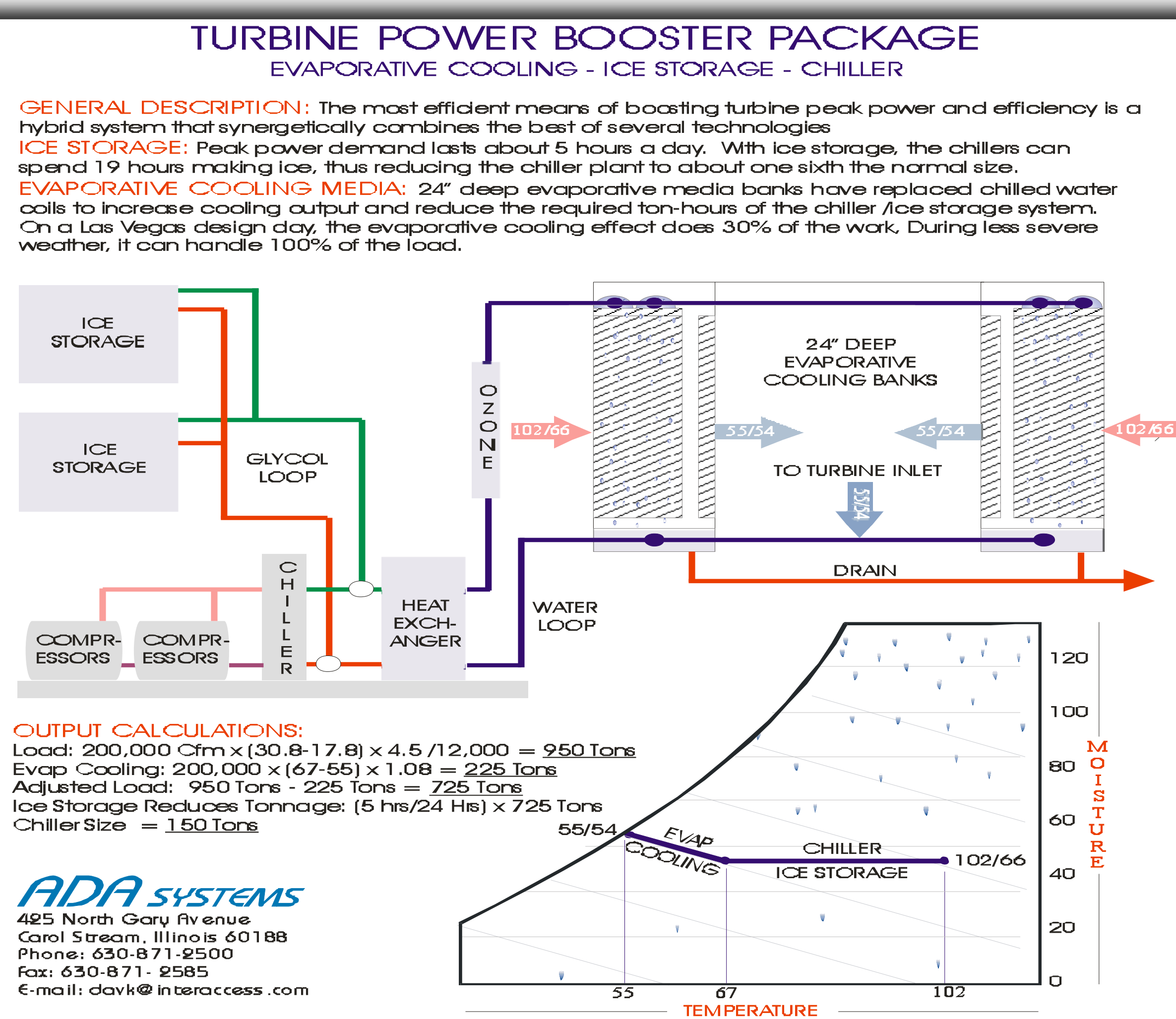
SUPPLY AIR ENTERING (F)	EXHAUST AIR ENTERING (F)	HOURS PER YEAR (Hrs)	SUPPLY AIR LEAVING (F)	EXHAUST AIR LEAVING (F)	BTU/HR RECOV-ERED (Btu/hr)	BTU/BIN RECOV-ERED (Btu/bin)	THERMS PER BIN /Furn Eff	SAVINGS PER BIN	PARA-SIDICAL LOSS (Kw)	PARA-SIDICAL LOSS ($)	NET SAV-INGS ($)
57	70	604	65	62	4.6E+05	2.77E+08	2,769	$ 2,077	8,951	$ 716	$ 1,361
52	70	581	64	58	6.3E+05	3.69E+08	3,688	$ 2,766	8,610	$ 689	$ 2,077
47	70	565	62	55	8.1E+05	4.58E+08	4,582	$ 3,437	8,373	$ 670	$ 2,767
42	70	572	60	52	9.9E+05	5.65E+08	5,648	$ 4,236	8,476	$ 678	$ 3,558
37	70	725	58	49	1.2E+06	8.44E+08	8,437	$ 6,327	10,744	$ 860	$ 5,468
32	70	869	57	45	1.3E+06	1.16E+09	11,644	$ 8,733	12,878	$ 1,030	$ 7,703
27	70	589	55	42	1.5E+06	8.93E+08	8,931	$ 6,698	8,728	$ 698	$ 6,000
22	70	371	53	39	1.7E+06	6.28E+08	6,280	$ 4,710	5,498	$ 440	$ 4,270
17	70	231	51	36	1.9E+06	4.32E+08	4,317	$ 3,238	3,423	$ 274	$ 2,964
12	70	164	50	32	2.0E+06	3.35E+08	3,354	$ 2,516	2,430	$ 194	$ 2,321
7	70	115	48	34	2.2E+06	2.56E+08	2,558	$ 1,918	1,704	$ 136	$ 1,782
2	70	89	43	34	2.2E+06	1.98E+08	1,980	$ 1,485	1,319	$ 106	$ 1,379
-3	70	53	38	34	2.2E+06	1.18E+08	1,179	$ 884	785	$ 63	$ 821
-8	70	27	33	34	2.2E+06	6.01E+07	601	$ 450	400	$ 32	$ 418
-13	70	11	28	34	2.2E+06	2.45E+07	245	$ 184	163	$ 13	$ 170
-17	70	2	24	34	2.2E+06	4.45E+06	44	$ 33	30	$ 2	$ 31

Evaporative Cooling:
Indirect With Typical Rooftop Unit
Case Study No. 4

- Industrial facility with high outside air requirements (100% OSA for cooling and 80% OSA for heating)
  - Standard rooftop mechanical units
  - Indirect evaporative precoolers
  - DX tonnage reduced by 50%
  - Heat recovery in winter operation

Evaporative Cooling:

Turbine Power Boost



TURBINE POWER BOOSTER PACKAGE

EVAPORATIVE COOLING - ICE STORAGE - CHILLER

GENERAL DESCRIPTION: The most efficient means of boosting turbine peak power and efficiency is a hybrid system that synergetically combines the best of several technologies

ICE STORAGE: Peak power demand lasts about 5 hours a day. With ice storage, the chillers can spend 19 hours making ice, thus reducing the chiller plant to about one sixth the normal size.

EVAPORATIVE COOLING MEDIA: 24" deep evaporative media banks have replaced chilled water coils to increase cooling output and reduce the required ton-hours of the chiller /ice storage system. On a Las Vegas design day, the evaporative cooling effect does 30% of the work. During less severe weather, it can handle 100% of the load.

OUTPUT CALCULATIONS:

Load: 200,000 Cfm x (30.8-17.8) x 4.5 /12,000 = 950 Tons

Evap Cooling: 200,000 x (67-55) x 1.08 = 225 Tons

Adjusted Load: 950 Tons - 225 Tons = 725 Tons

Ice Storage Reduces Tonnage: (5 hrs/24 Hrs) x 725 Tons

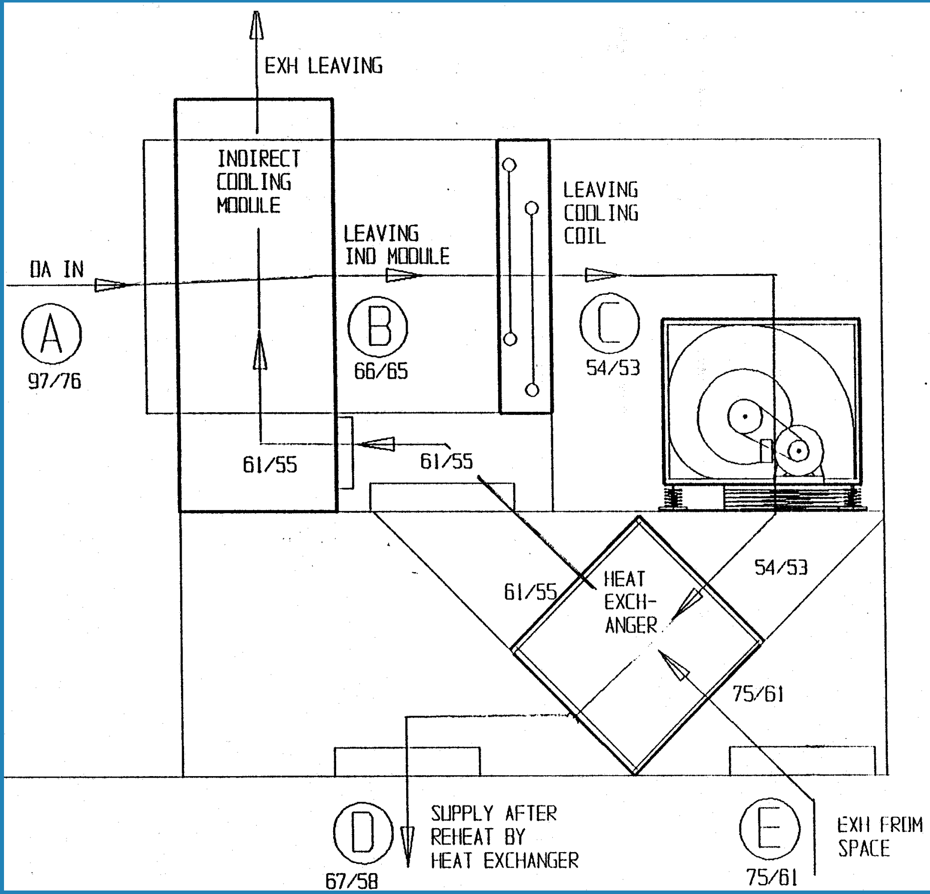
Chiller Size = 150 Tons

ADA SYSTEMS
425 North Gary Avenue
Carol Stream, Illinois 60188
Phone: 630-871-2500
Fax: 630-871- 2585
E-mail: davk@interaccess.com

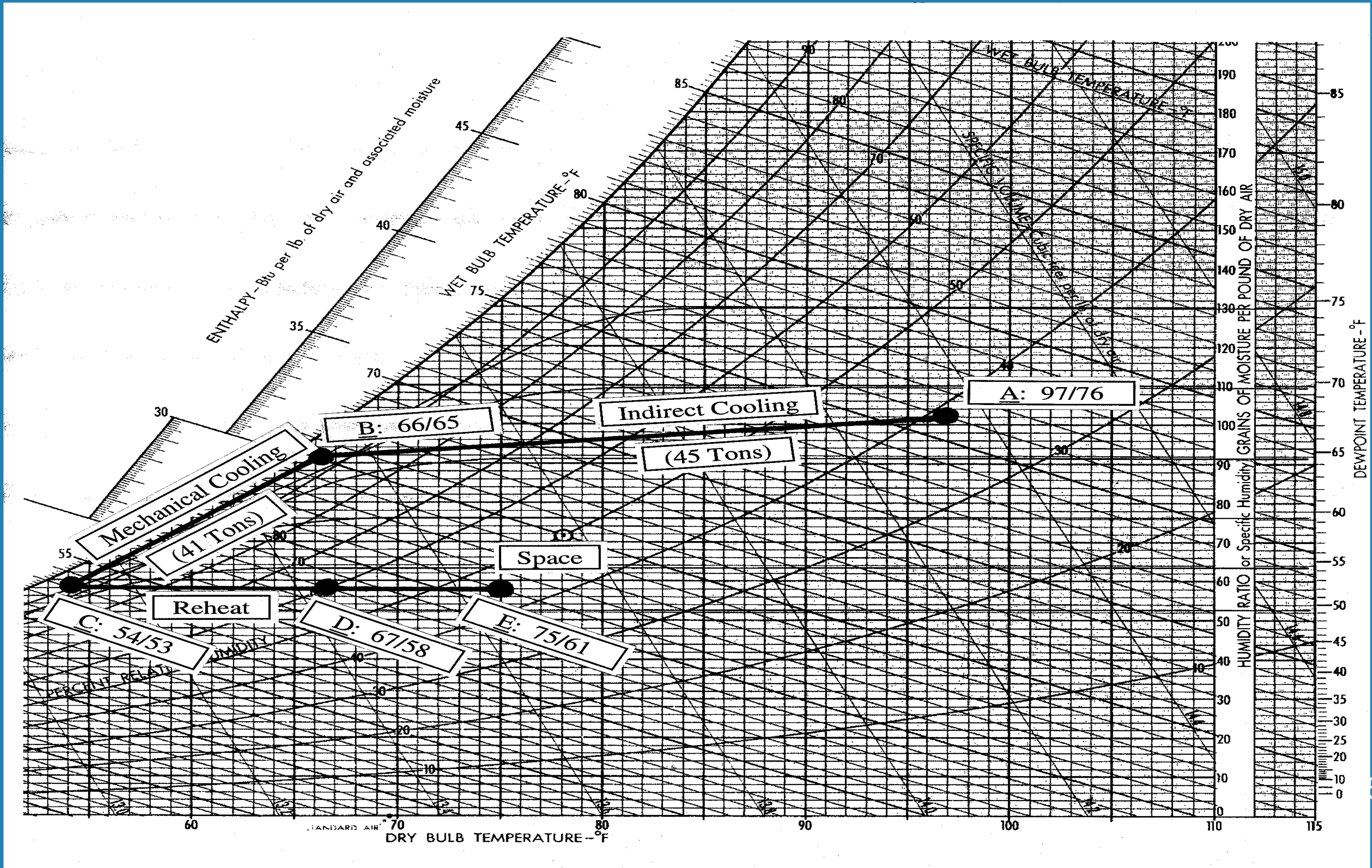
Evaporative Cooling:

Indirect/Mechanical (Low Energy Reheat)

- Facilities with high OSA needs often require expensive reheat
- Components of a low energy reheat system:
  - Indirect evaporative pre-cooler
  - Mechanical cooling coil
  - Secondary heat exchanger



Evaporative Cooling:
Indirect/Mechanical (Low Energy Reheat)



Evaporative Cooling:
Hybrid (Multi-Functional) System

- Wausau West High School, Wausau, WI
- Problems they were facing:
  - Expensive retrofit of existing chiller plant
  - Severe indoor air quality
  - Non-compliance with Standard 62

Evaporative Cooling:
Hybrid (Multi-Functional) System

- The **Regenerative Double Duct™** is a hybrid, multi-component/function design that is proving to be one of the most energy efficient HVAC systems available. Its major components are:
  - **Indirect Evaporative Cooler (IDEC)**
    - First stage cooling
    - First stage heating
    - Limited capacity to act as a cooling tower
  - **Direct Evaporative Cooler (DEC)**
    - Direct evaporative cooling (when conditions permit)
    - Air filtration/scrubbing
    - Humidification

Evaporative Cooling:
Hybrid (Multi-Functional) System

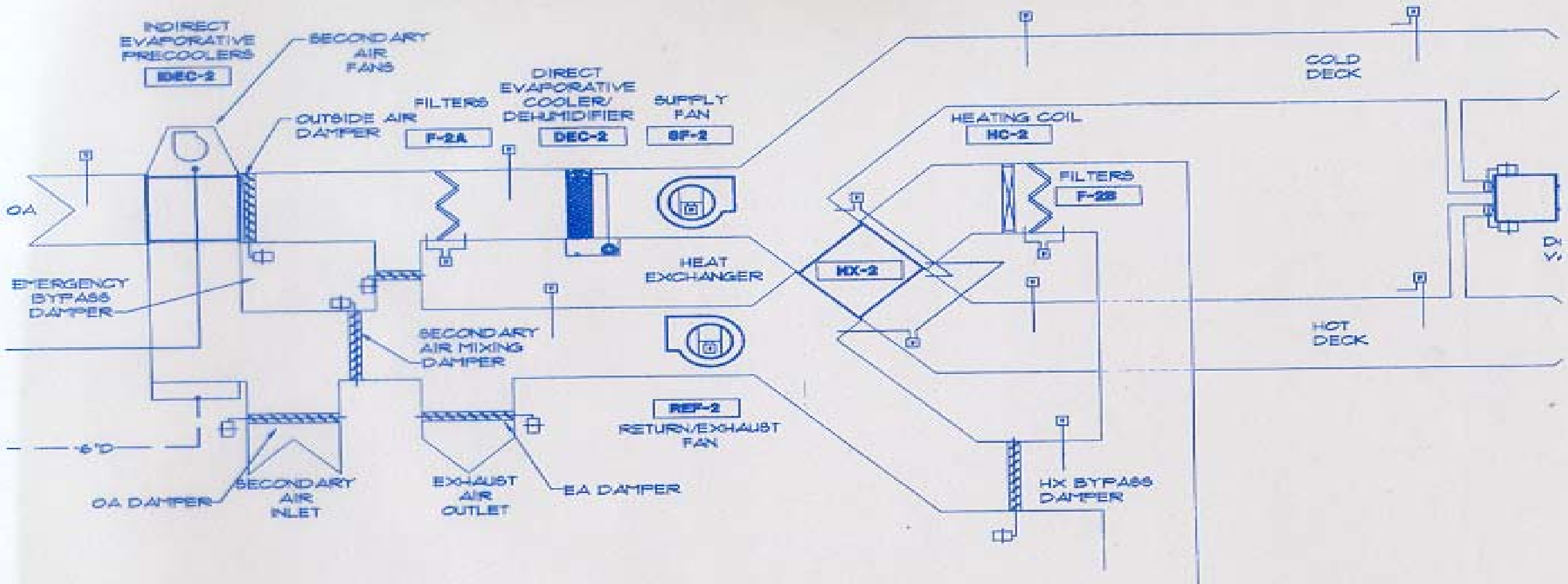
- **Secondary Plate-And-Frame Heat Exchanger (HX)**
  - Provides heating for the hot deck
  - Sub-cools building exhaust
- **Thermal Energy Storage**
  - Makes ice during less expensive time of day
  - Flattens out the demand curve
- **Chilled Water**
  - Supplemental cooling
  - Supplemental dehumidification
- **Boilers**
  - Perimeter heating
  - Supplemental heating

Evaporative Cooling:
Hybrid (Multi-Functional) System

- **Heating Coil**
  - Pre-heat (on building exhaust)
  - Supplemental heat
  - Defrost (for IDEC)
- **Filtration**
  - Supply
  - Exhaust
- **Water Treatment**
  - Ozonation
  - Pulsed Power

Evaporative Cooling:
Hybrid (Multi-Functional) System

DUAL DUCT MULTI-ZONE
WAUSAU SCHOOL DISCTRICT (WISCONSIN)



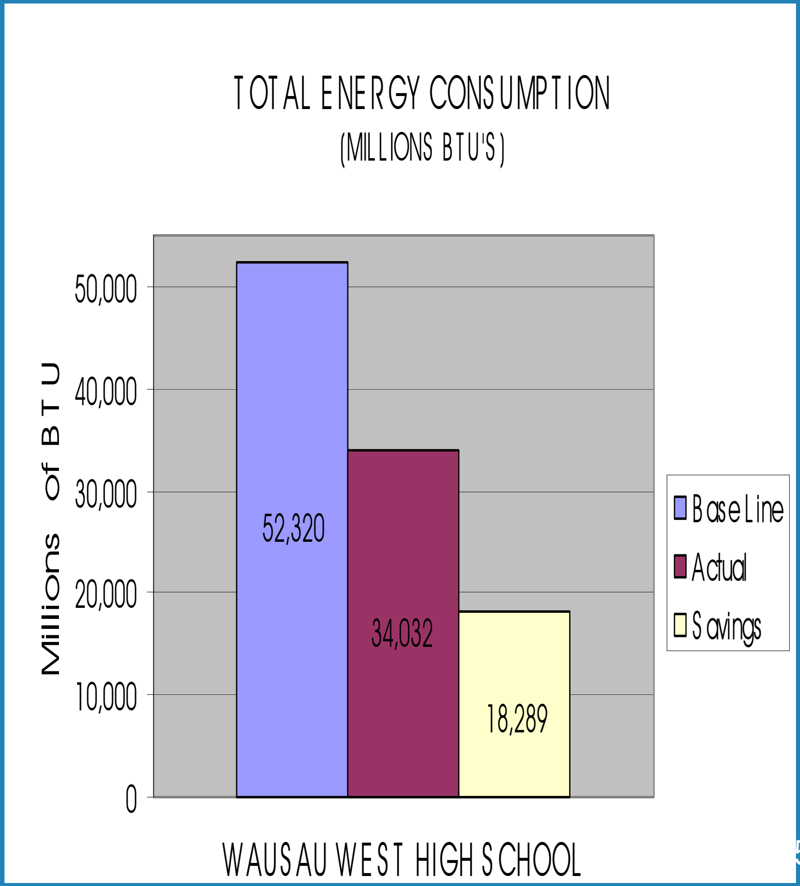
1) Energy Efficiency is greatly enhanced through the use of evaporative coolers and air-to-air heat exchangers.
2) IAQ is improved by the use of large quantities of outdoor air and through the washing of the supply air inside the DEC unit which extracts condensible gases responsible for sick building syndrome and which cannot be removed by conventional filters.
3) Hydronic perimeter heating is used to prevent building heat loss.
4) Dual-Duct VAV boxes are used to provide cooling to the individual building zones.
5) Very inexpensive cooling is provided by the IDEC(idec-2) unit which provides first stage cool, and the DEC(dec-2) unit which provides second stage cooling.
6) Auxilliary cooling can be added in the future - if needed - by using a chil cool supply water (through a secor heat exchanger loop) before enteri DEC unit.
7) The HX (hx-2) heat exchanger free heating for the hot deck. In h weather, the HX is bypassed.
8) The heat exchanger located wit IDEC recovers heat and cooling fr building exhaust.

Evaporative Cooling:
Hybrid (Multi-Functional) System

- Wausau West High School
- Area: 275,000 S/F
- System Type: Regenerative Double Duct
- Primary Heating Plant Reduction: 60%
- Primary Cooling Plant Reduction: 92%
- Gross Energy Use Reductions:
  - Natural Gas: 38%
  - Electricity (kWh): 27.8%
  - Electrical Demand: 25%
- Gross Energy Cost Reductions: 29.3%

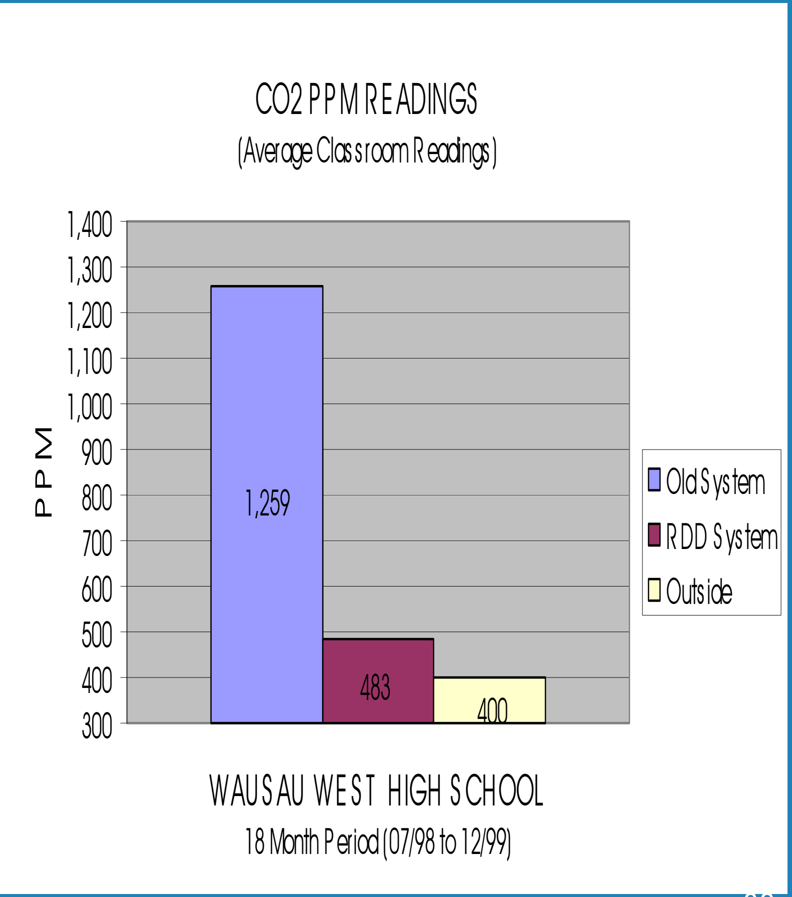
Evaporative Cooling:
Hybrid (Multi-Functional) System

- “Base Line” energy consumption based on the former HVAC system that utilized **minimum outside air** and recirculated a majority of existing building air
- “Actual” energy consumption based on the new **100% outside air** HVAC system



Evaporative Cooling:
Hybrid (Multi-Functional) System

- ASHRAE Standard 62.1-2001 uses an indoor to outdoor differential concentration not greater than 700 ppm of CO_2 as an indicator of acceptable indoor air quality

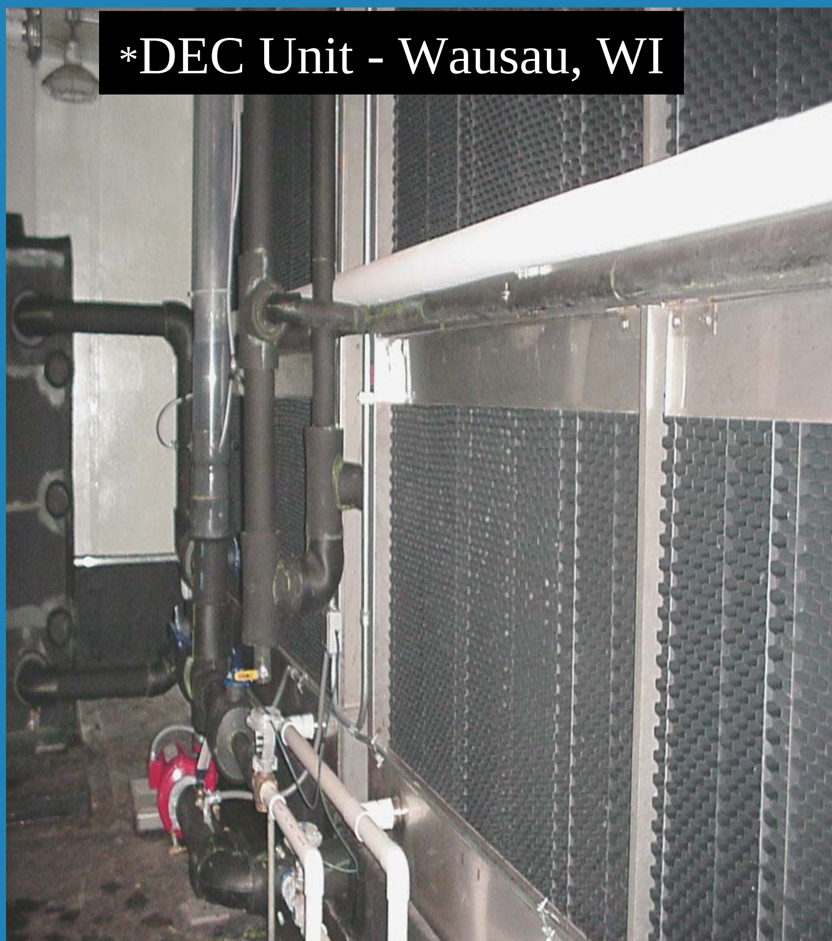


Evaporative Cooling:
Hybrid (Multi-Functional) System

- Advantages to the Hybrid system:
  - Lower first cost (especially for new construction)
  - Reduced energy usage (up to 70%)
  - Improved indoor air quality
    - Larger amounts of outdoor air
    - Direct section acts as an air scrubber

Evaporative Cooling:
Hybrid (Multi-Functional) System

Evaporative Cooling:
Hybrid (Multi-Functional) System


*DEC Unit - Wausau, WI

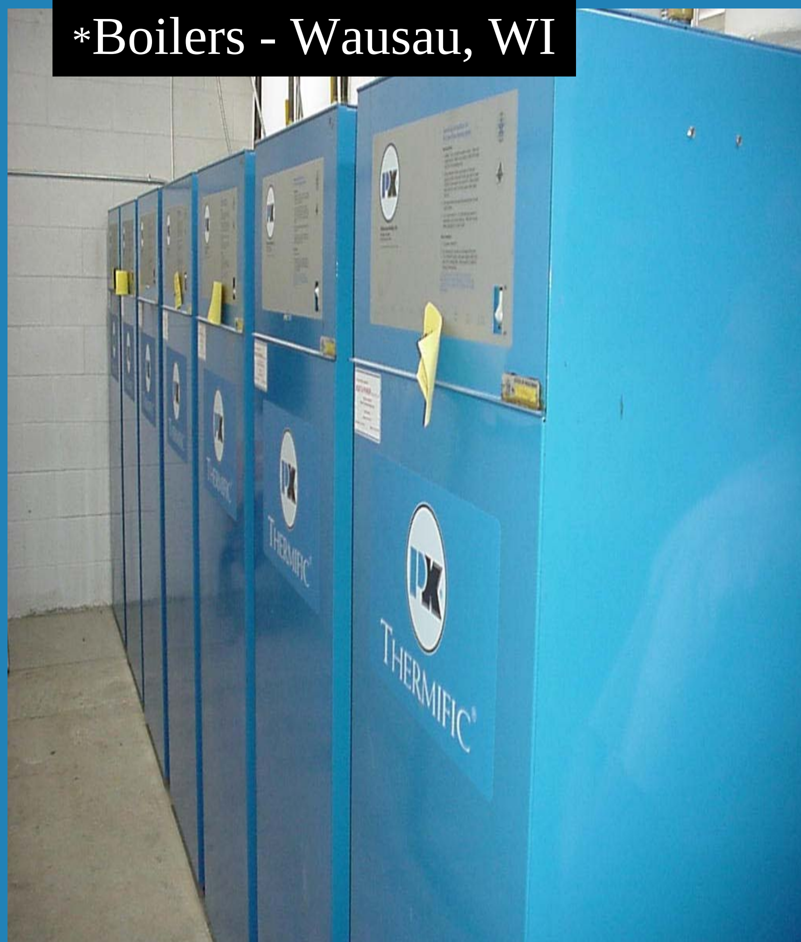

*70-Ton Chiller - Wausau, WI

Evaporative Cooling:
Hybrid (Multi-Functional) System

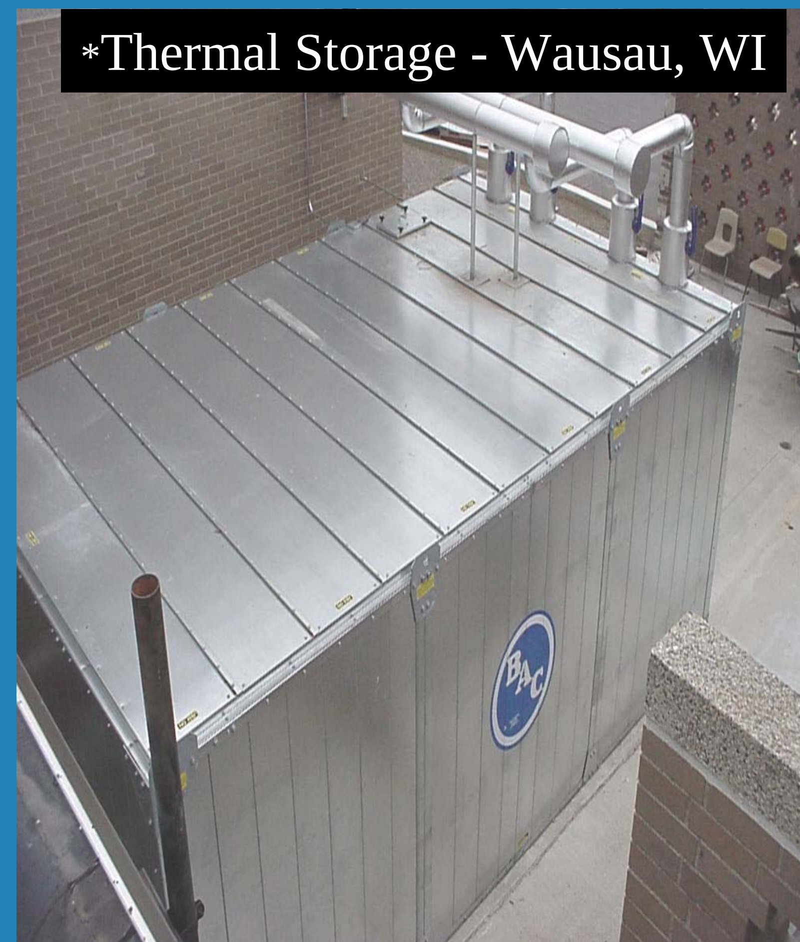
*IDEC Unit - Wausau, WI

*Ozonation - Wausau, WI

Evaporative Cooling:
Hybrid (Multi-Functional) System



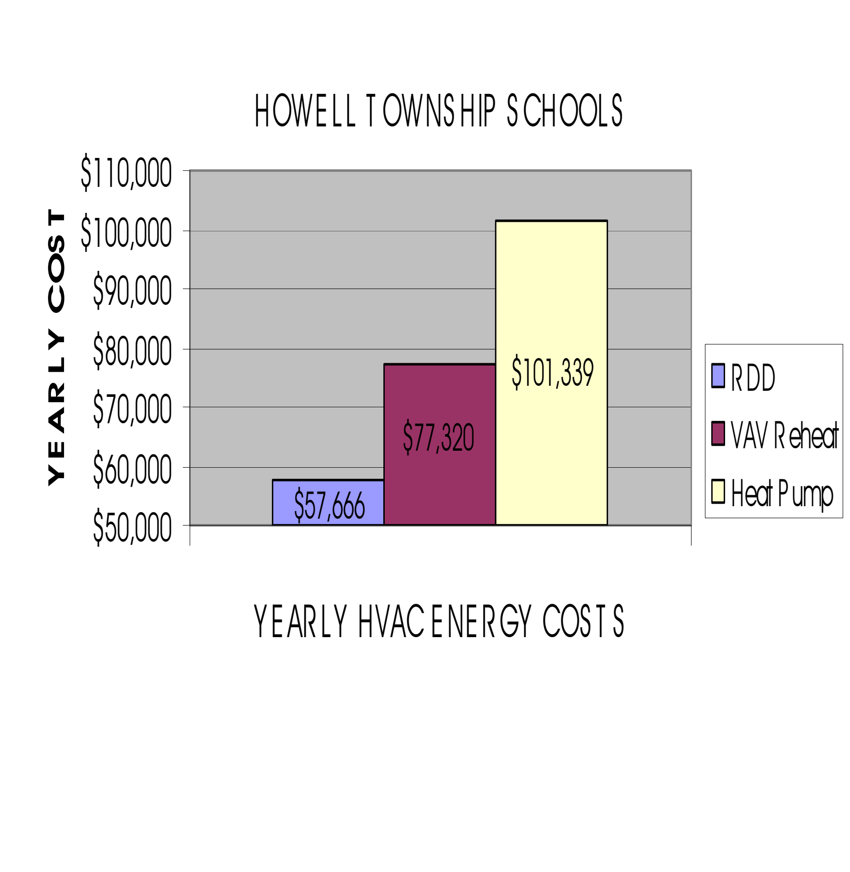
*Boilers - Wausau, WI



*Thermal Storage - Wausau, WI

Evaporative Cooling:
Hybrid (Multi-Functional) System

- Independent study commissioned by a New Jersey utility company comparing 3 proposed HVAC systems for 3 new schools
- With the Regenerative Double Duct™ HVAC design, these 3 schools will become the first LEED silver certified schools in New Jersey



Evaporative Cooling:
Hybrid (Multi-Functional) System

*IDEC unit - Howell Township, NJ

Evaporative Cooling:
Hybrid (Multi-Functional) System

*Thermal Energy Storage - Howell Township, NJ

Evaporative Cooling:
Hybrid (Multi-Functional) System

Evaporative Cooling:
Hybrid (Multi-Functional) System

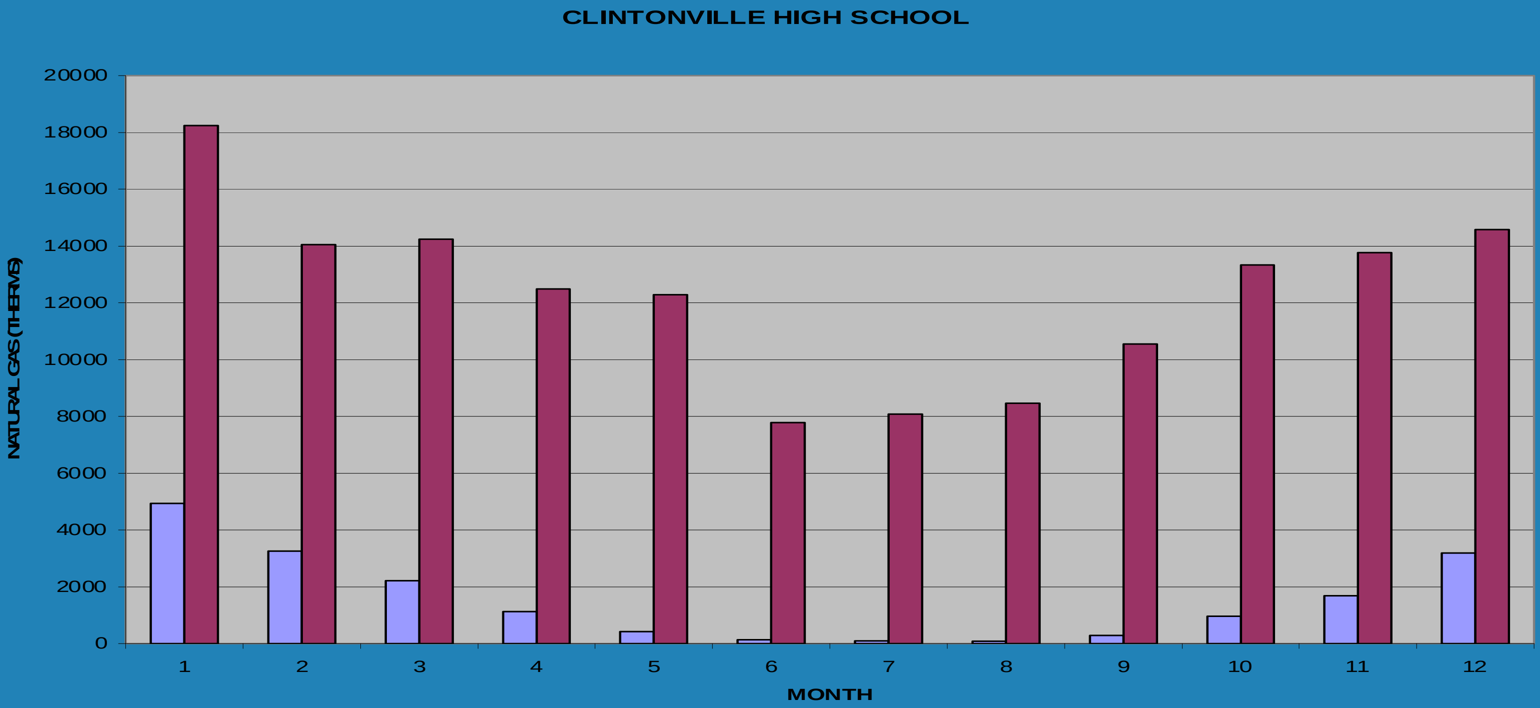
*Boilers - Howell Township, NJ

*Pulsed Power Water Treatment

Evaporative Cooling:
Hybrid (Multi-Functional) System

*Clintonville High School: Natural Gas Use

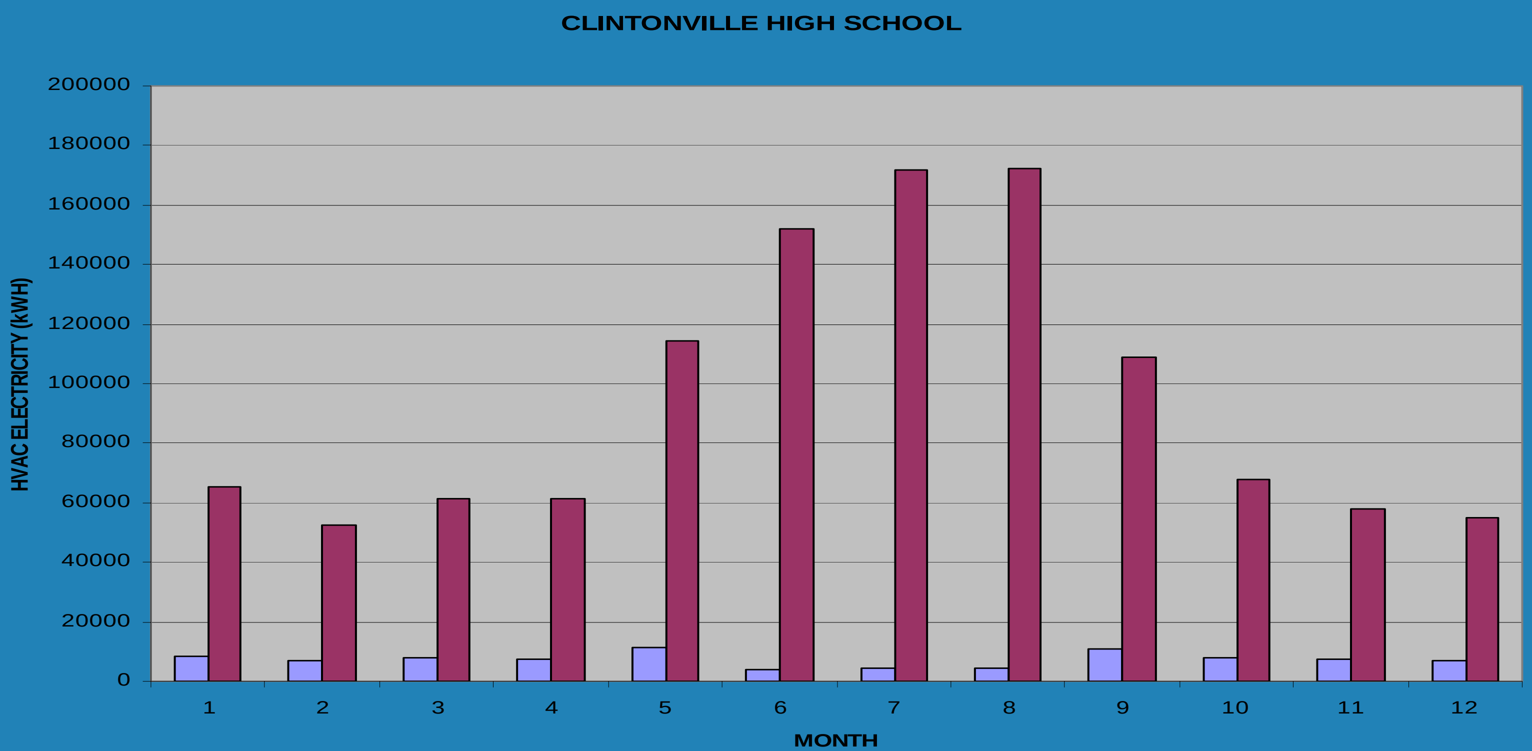
(Projected Energy Consumption Using the Regenerative Double Duct™ Compared to Gas Absorption Chillers and Boilers)



Evaporative Cooling:
Hybrid (Multi-Functional) System

*Clintonville High School: Electrical Use

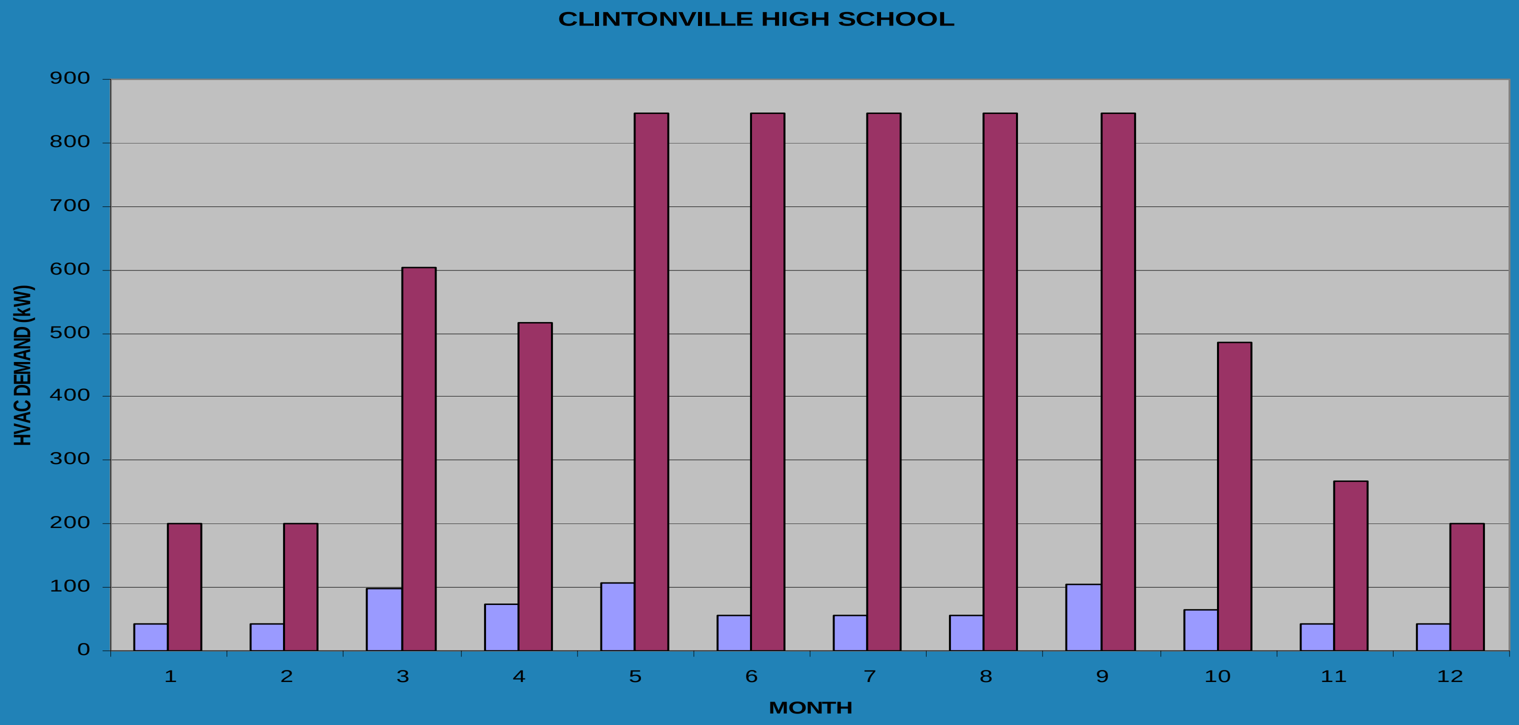
(Projected Energy Consumption Using the Regenerative Double Duct™ Compared to Gas Absorption Chillers and Boilers)



Evaporative Cooling:
Hybrid (Multi-Functional) System

*Clintonville High School: HVAC Demand

(Projected Demand Using the Regenerative Double Duct™ Compared to Gas Absorption Chillers and Boilers)



Evaporative Cooling:
Hybrid (Unitary/Integrated) System

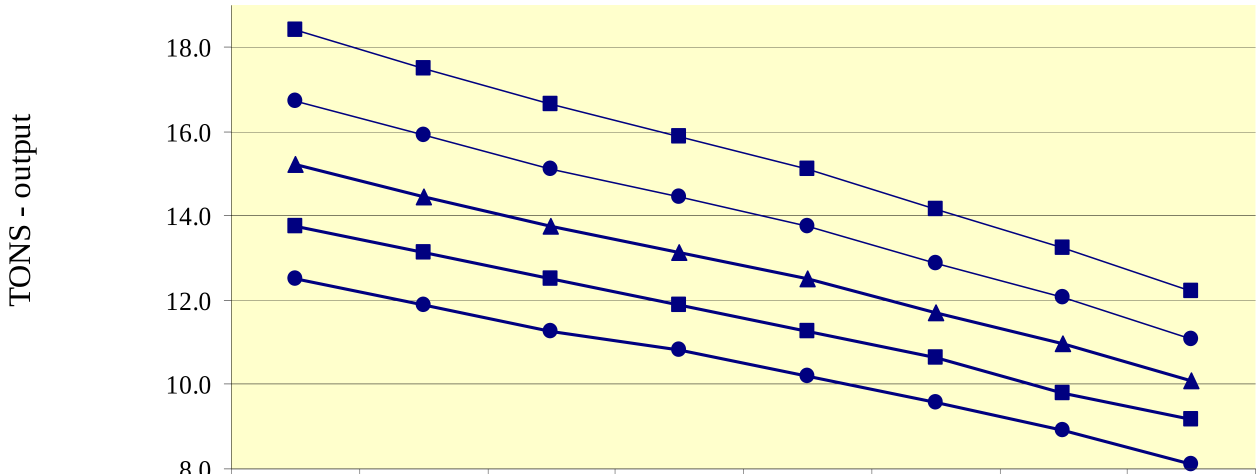
- Roof-top units can be designed with many of the same components and efficiencies of the built-up systems
  - Indirect evaporative precooling/preheating
  - Direct evaporative cooling/humidification
  - Evaporative condenser
  - Downsized centrifugal compressor and cooling coil
  - Downsized hot water coil or furnace

Evaporative Cooling:
Hybrid (Unitary/Integrated) System

*ARI conditions: 130°F condensing and 45°F suction temperatures.

**ADA Systems'* new hybrid design will have operating conditions of 90°F condensing and 50°F suction temperatures.

CAPACITY - TONS
(Output of 10 ton scroll compressor)



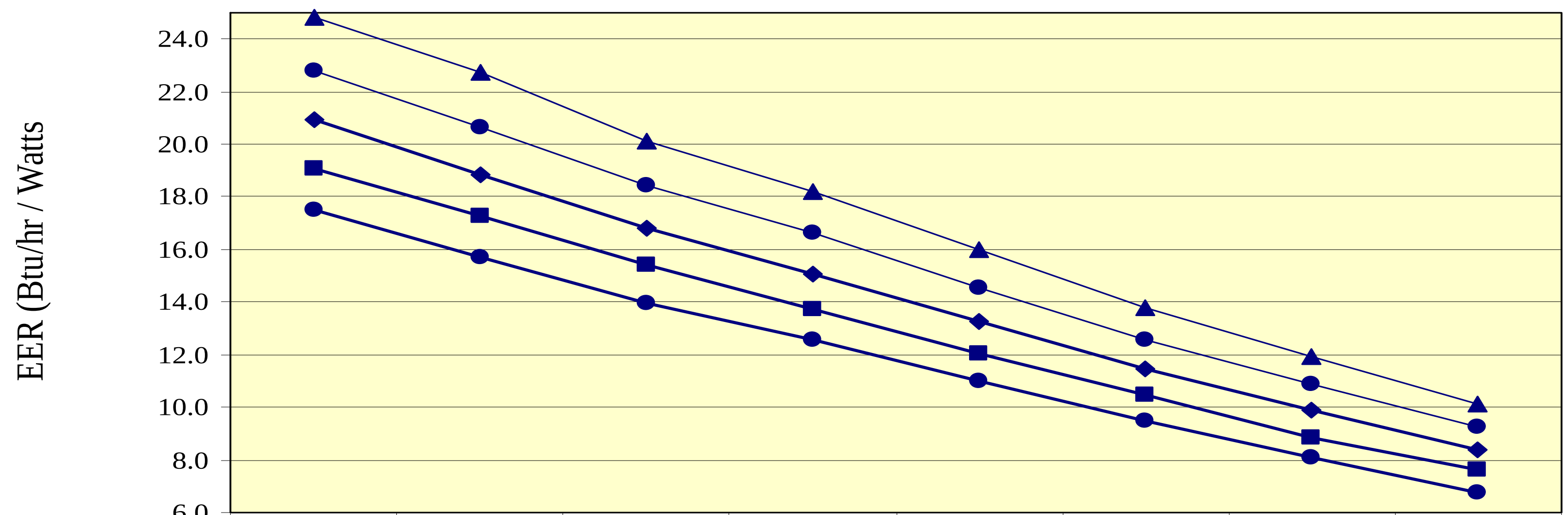
	80	90	100	110	120	130	140	150
35F SUCTION	12.5	11.9	11.3	10.8	10.2	9.6	8.9	8.1
40F SUCTION	13.8	13.1	12.5	11.9	11.3	10.6	9.8	9.2
45F SUCTION	15.2	14.5	13.8	13.1	12.5	11.7	11.0	10.1
50F SUCTION	16.7	15.9	15.1	14.4	13.8	12.9	12.1	11.1
55 SUCTION	18.4	17.5	16.6	15.9	15.1	14.2	13.3	12.2

OUTPUT TONS verses CONDENSING TEMP

Evaporative Cooling:
Hybrid (Unitary/Integrated) System

EER

(10 Ton Scroll Compressor)



	80	90	100	110	120	130	140	150
35 F Suction	17.5	15.7	14.0	12.6	11.0	9.5	8.1	6.8
40 F Suction	19.1	17.3	15.4	13.7	12.0	10.5	8.9	7.6
45 F Suction	20.9	18.9	16.8	15.0	13.3	11.5	9.9	8.4
50 F Suction	22.8	20.6	18.4	16.7	14.5	12.6	10.9	9.2
55 F Suction	24.8	22.7	20.1	18.2	16.0	13.8	11.9	10.1

EER verses CONDENSER TEMP

Evaporative Cooling: Conclusions (Part 1)

- Classical HVAC system strategies and equipment are not meeting the client's needs. Classical HVAC solutions are the problem
    - They are primarily constructed around energy intensive processes
    - Reliance on ventilation reduction is the primary cause of air quality problems
    - Recirculation compromises indoor air quality and energy efficiency
    - They place indoor air quality and energy conservation goals in fundamental conflict
- New HVAC system strategies are needed…better engineering is required

Evaporative Cooling: Conclusions (Part 2)

- Truly "green" HVAC systems are attainable with simple technologies that are readily available
- Benefits of these "green" systems
  - Competitive construction costs
  - improved indoor air quality
  - reduced energy consumption
  - reduced heating/cooling plants
  - easy to maintain
- Both Direct and Indirect evaporative cooling are simple, reliable processes which will take you where you want to go