TOTAL BUILDING AIR MANAGEMENT: WHEN DEHUMIDIFICATION COUNTS

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ABSTRACT

Industry trends toward stringent indoor air quality codes, spearheaded by ASHRAE 62-89: *Ventilation for Acceptable Indoor Air Quality*, present four challenges to the building industry in hot and humid climates:

1. Infusion of large quantities of make-up air to code based on zone requirements
2. Maintenance of tight wet bulb and dry bulb temperature tolerances within zones based on use
3. Energy management and cost containment
4. Control of mold and mildew and the damage they cause

Historically, total air management of sensible and latent heat, filtration and zone pressure was brought about through the implementation of non-integrated, composite systems. Composite systems typically are built up of multi-vendor equipment each of which perform specific, independent functions in the total control of the indoor air environment. Composite systems have a high up-front cost, are difficult to maintain and are costly to operate.

Today, emerging technologies allow the implementation of fully integrated system for total building air management. These systems provide a single-vendor solution that is cost effective to purchase, maintain and operate. Operating saving of 23% and ROIs of 2.3 years have been shown. Equipment specification is no longer based primarily on total building load. Maximum benefits of these dynamic systems are realized when systems are designed with a total operating strategy in mind. This strategy takes into consideration every factor of building air management including:

1. Control of sensible heat
2. Balance management of heat rejection
3. Latent heat management
4. Control of process hot water
5. Indoor air quality management
6. Containment of energy consumption
7. Load shedding

INDUSTRY TRENDS IN BUILDING AIR MANAGEMENT

ASHRAE 62-89, and the much discussed amendments to this document, is changing the way that the commercial building industry conducts business. As Indoor Air Quality (IAQ) becomes a major theme of regulators, it also becomes a major concern within the building industry, particularly in the commercial building industry. Failure to comply with industry standards can result in law suits and stiff penalties. Every design build contractor, commercial architect, design engineer and commercial building owner is at risk.

There is much debate in the industry about what constitutes acceptable Indoor Air Quality, but nearly everyone agrees that meeting ASHRAE 62-89 standards for make-up air is one good way to avoid code violation. Meeting code requirements in hot and humid climates can pose a dilemma. Alternatives include:

1. Ignore the codes, and risk litigation

2. Bring in outside air to code (usually 15 CFM per person) and along with it, bring in large

quantities of sensible and latent heat which may result in the growth of mold and mildew. This alternative reduces indoor air quality, increases the potential for structural damage and increases energy consumption

3. Invest in composite systems for dehumidification and air tempering. This reduces the potential of mold, mildew and related damages while increasing first cost, operating costs and the cost of system maintenance

4. Investigate new technologies that promise a total building air management solution

THE TRADITIONAL APPROACH

Traditionally, an IAQ-sensitive composite system designed for hot and humid climates would consist of two or more of the following:

1. Central or zoned air conditioning equipment
2. Make-up air equipment (zoned or central)
3. Dehumidification equipment

In some cases, passive dehumidification generated as a by-product of the air cooling process, is considered adequate and no further dehumidification is provided. In other instances when humidity control is essential, a desiccant dehumidification system is specified.

The traditional approach to controlling indoor air quality focuses on bringing in make-up air to code, mixing it with pre-conditioned return air, then heating and/or cooling the mixture to meet occupant comfort demands. ASHRAE 62-89 specifies at least 15 CFM per person.

In Denver Colorado where relative humidity of outdoor air is low and outdoor design temperature is 92° F DB/65° F WB, this may be a cost effective method of assuring high IAQ. In other parts of the country — Houston, Texas (96° F DB/80° F WB) or Miami, Florida (92° F DB/80° F WB) for example — 15 CFM make-up air per person may pose as many Air Quality problems as it solves. Here is why.

Need to Adjust To Variable Occupancy Per Zone

Problem. In many commercial buildings, occupancy per zone changes unpredictably over time. Conference rooms in office buildings, public spaces in malls, supermarkets, and multi-plex theaters are examples of spaces where zone occupancy is not constant or predictable. As occupancy changes, the total volume of make-up air demanded by code also changes proportionately. Conventional air-conditioning and make-up air systems are not designed to adapt zone by zone to changing occupancy. In consequence, when the ventilation system is designed to bring in make-up air based on maximum occupancy (as ASHRAE 62-89 recommends), the system is oversized for the make-up air requirements of average occupancy conditions.

Consequences. The inability to match make-up air to occupancy results in the following:

1. Oversized make-up air and air-conditioning systems increase first cost (equipment plus installation)
2. Oversized equipment results in excessive energy consumption
3. When equipment is oversized, compressors operate for shorter periods of time than is optimal for maximum equipment life, resulting in shortened equipment life cycle and increased maintenance cost

Need for Variable Make-up Air Based On Actual IAQ

Problem. Although 15 CFM per person may be the code, it does not always accurately represent the actual IAQ requirements of the zone. If the zone needs only 7 CFM per person to maintain high quality IAQ, the cost of bringing in and conditioning 15 CFM per person is more than double that required to provide for optimum occupancy comfort.

Consequences. Excessive make-up air results in the following:

1. Air tempering of excessive make-up air results in unnecessary energy consumption
2. Equipment operates more than is required causing excessive maintenance costs

Need For Air Filtration

Problem. Outdoor air is not always "fresh" air. In many industrial centers, outdoor air may contain more particulate contamination than indoor air. Further, in coastal environments outdoor air may be highly corrosive. As a result, in many commercial centers in hot and humid areas, outdoor air must be intensively filtered before it is useful as a way to improve indoor IAQ. Filtration for commercial buildings built along the coast can require special equipment especially designed to accommodate the salt-impregnated air. Further, any filtration system requires careful monitoring to assure that clogging does not occur.

Consequences. The opportunity for decreasing IAQ in industrial and coastal regions is directly proportional to the amount of make-up air brought into the facility.

1. As IAQ falls as a result of improperly maintained filters potential for code violation increases
2. Prolonged exposed of equipment and structural members to corrosive air increases maintenance costs and decreases equipment life

Need For Dehumidification

Problem. To avoid mold and mildew and the damage they cause, effective dehumidification systems are mandated in hot and humid climates. Zone dehumidification can occasionally be accomplished as a result of zone air conditioning systems. However, these systems provide effective dehumidification only as long as they are in operation. When the unit is turned off during cooler weather or when zones are unoccupied, humidity levels within the zone rise. The choice with this type of equipment can often be between cold and dry, or warm and damp. As an alternative to zone air-conditioning systems, desiccant systems are often employed along with the cooling systems to dehumidify the entire building or multi-zone cells. When properly designed, these systems can effectively control humidity levels within the building.

Consequences. Without adequate dehumidification, mold and mildew can cause major structural damage in hot and humid climates. In addition:

1. Room air conditioning often cannot meet indoor comfort needs of zone occupants while maintaining relative humidity at ranges below that required to control the growth of mold and mildew.
2. Desiccant systems effectively dehumidify but with the penalty of increased first cost and high maintenance
3. Most conventional methods of dehumidification increase maintenance costs, either of the facility or of the dehumidification equipment itself

Equipment Limitations

Problem. Conventional HVAC systems implemented in systems designed for hot and humid climates can result in unreliable delivery of make-up air. Preset damper positions of manual air intake dampers do not reliably deliver the exact amount of make-up air required by code. In addition, the quality of air filtration is uncertain when the condition of the filter is unknown.

Consequence. Codes are not reliably met.

1. This provides an increased opportunity for code violation.
2. Fixed damper positions cannot adjust dynamically to the actual IAQ needs of the indoor environment, only for the conditions they were set
3. When the manual damper is set to accommodates maximum occupancy, make-up air intake will be more than required most of the time, resulting in excessive energy consumption
4. When the manual damper is set for average occupancy, make-up air intake will be either more than or less than required most of the

time, vacillating between excessive operating costs or an increased risk of code violation

Summary

The designer of conventional HVAC systems for commercial buildings in hot and humid climates is limited in what he can design for his customer. The contractor can give the owner two choices:

1. The owner pays a high cost up front for sophisticated, composite technology that is expensive to operate and maintenance intensive, or

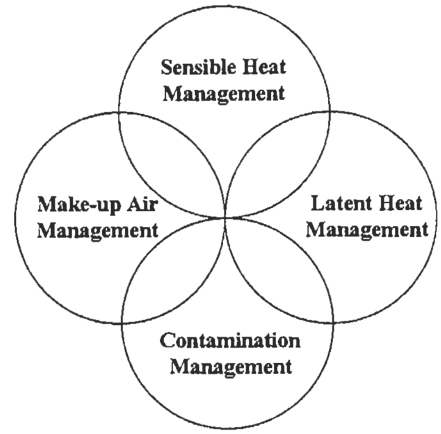
2. The owner controls his capital investment by buying a conventional central (or zoned) HVAC system and pays over the life of the equipment with high energy consumption, high structural and equipment maintenance costs and nagging worry about potential code violation.

EMERGING TECHNOLOGIES FOR TOTAL BUILDING AIR MANAGEMENT

Until recently, the architect, owner and contractor had no alternative to the two options cited above. However, in 1995 new technology was developed that combines many of the best features of a composite system within a single pre-engineered HVAC unit. This equipment is designed to address all the problems presented by hot and humid climates. It provides zone management of:

1. Sensible heat
2. Latent heat
3. Make-up air intake
4. Particulate contamination

Total Building Air Management for High Indoor Air Quality &Occupant Comfort



This equipment tightly manages indoor air quality to code and increases occupant comfort in commercial structures. At the same time, it meets the total building air management demands of commercial building owners in hot and humid climates by controlling:

1. Capital outlay
2. Maintenance costs
3. Energy consumption
4. Risk of code violation

Results from monitoring early installations of this equipment, sponsored by the Electric Power Research Institute, Inc. (EPRI), point to significant and quantifiable advantages of this technology over conventional HVAC systems. As illustrated in the table below, advantages can be shown to exist for most environments in the United States and Canada, but are especially noteworthy for hot and humid climates.

Comparison of Single/Dual Path Systems*

		Dallas	Wash. D.C.	New Orleans
Installed	Single Path	2.74	2.78	3.18
*Capacity***	Dual Path	2.32	2.15	2.70
Electric	Single Path	3.73	3.61	4.09
Demand	Dual Path	2.93	2.54	3.22
Energy	Single Path	15.29	9.69	18.53
*Use****	Dual Path	11.72	8.29	15.37
Sizing	Single Path+	1.0	1.0	1.0
Parameter	Dual Path++	500	500	500

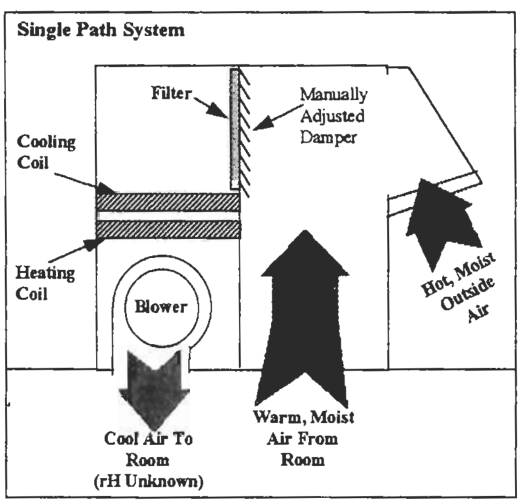
* *Table courtesy of EPRI, Inc. Palo Alto, California*
** Ton/1000 Sq Ft. *** kWh/sq. ft/year
+ CFM/sq. ft ++ CFM/ton

How the system works
The system bases its efficiency on water source heat pump technology. To this it adds two air handling paths.

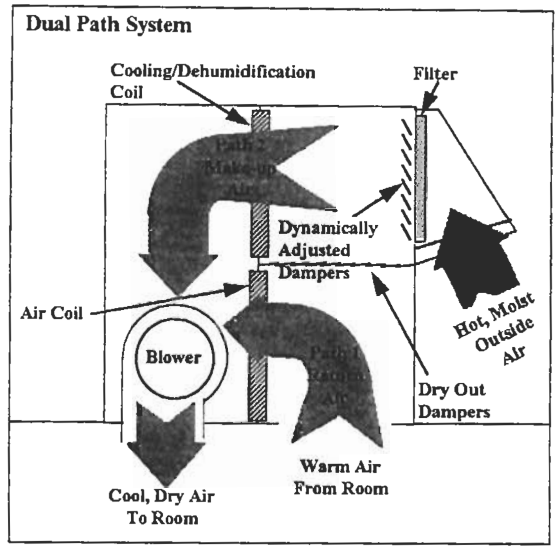
One air handling path cools and dehumidifies outside air. Dynamically operated dampers bring in carefully measured amounts of make-up air as required by code based on varying zone occupancy. Outside air is filtered through a multi-layer filter bank. As much as four (4) inches of filters can be accommodated. Damper operation is dynamically controlled by CO_2 (or IAQ) sensors to accurately match the amount of make-up air intake to the IAQ requirements of the building. This technique insures that indoor air quality codes are met.

The second air handling path conditions and dehumidifies return air as necessary before mixing it with conditioned outside air.

Dual Path Systems Vs. Single Path Systems
A conventional single path system is shown below. Note that moist make-up air and drier room air are mixed before conditioning occurs. Dehumidification is a by-product of the cooling process. The exact relative humidity in the building supply air is not known.



In hot, humid climates, where dehumidification is critical, the strategy of specifying over-size equipment to meet latent heat loads increases capital expense and operating costs.



In contrast, a dual path system, shown above, accurately controls temperature, humidity and the amount of make-up air brought into the building. The dual path design allows for precisely sized coils to meet the conditioning demands of each air stream.

TOTAL BUILDING AIR MANAGEMENT WITH DUAL PATH TECHNOLOGY

The dual-path system includes accurate control of humidity, temperature and make-up air in a single engineered system. Engineers or facilities managers can easily specify these prefabricated, pre-engineered equipment. The equipment can be specified in many sizes and configurations to meet a wide variety of structural constraints. Although the equipment used in the test study is a rooftop mounted unit, other models are available suitable for installation above the ceiling, in a utility closet or in an equipment room. Installation is a comparatively simple process once the water loop is installed System balancing takes hours rather than days. This reduces on-site labor and start-up costs.

Latent Temperature Control By Zone
Relative humidity is accurately controlled by zone. As a result, mold and mildew spores do not have a chance to grow. This enhances indoor air quality, while reducing the risk of structural damage. Dehumidification to a relative humidity

of 50% is typical. Dual path systems assure that no untreated air enters the facility.

Ventilation To Code By Zone

Like any Water Source Heat Pump product, the dual path system is zoned controlled. Make-up air requirements of one zone can be accurately met based on zone occupancy. CO_2 (or IAQ) sensors control make-up air intake. As a result, only the amount of outside air required to meet code is brought into the building envelope. This means that excessive amount of outside air do not have to be cooled, dehumidified, and filtered, prolonging filter and equipment life, and decreasing energy consumption. Even at low air flow rates, the system can meet 100% of ventilation requirements by zone. An external enthalpy control point optimizes the operation of the equipment under variable outside ambient conditions.

Sensible Temperature Control By Zone

Dual path systems control latent and sensible heat by zone. Adjacent zones (each with its own dual path system) can be individually cooled (or heated based on occupant comfort. This means that an occupied zone can be cooled while vacant zones can be left without conditioning. Zoned humidity and temperature control reduces operating costs and increases the comfort of zone occupants.

Filtration Systems

The dual path system is built to accommodate up to four (4) inches of filter in a filter bank. Filters suitable for this equipment include HEPA 60% three stage, filters. These high efficiency filters can be applied without significant pressure drop or reduction in equipment operating efficiency. When filters become clogged, a filter light (and/or alarm) is activated to alert maintenance staff of the need to change filters. Rapid response to filter alarms enhances indoor air quality and prolongs equipment life.

Avoided Contamination

Abundant condensate from the dehumidification coil constantly flushes the drain pan while dry return air avoids condensate on primary coils. Together, this virtually eliminates standing water in drain pans and associated mold, milder and bacteria growth.

Alternative Refrigerants

The dual path system is manufactured to operate with zero ODP Refrigerants. R-407C, used at the monitored site, is an environmentally acceptable refrigerant with zero ozone depletion potential. This refrigerant eliminates the potential for environmental damage during manufacturing and service of the equipment, and has made this equipment a central feature of "Green" construction.

Energy Management

Because each path of the dual path system treats only air streams from only one source, coils can be sized for their primary use, improving operational efficiency compared to conventional single path equipment. EERs of 14 are readily achievable. Studies of the test installation, conducted by the University of Colorado, show a potential cost savings of 22.6% over air cooled HVAC products paired with a gas fired dehumidification system. See table below for comparisons from this study.

Single Path kWh/Yr	Dual Path kWh/Yr	Savings kWh/Yr
3,538,554	2,738,732	799,822

(DOE 2.1E Study # 40-250.02)

Although some savings result from high operating efficiencies, much of the operating cost advantages come from the ability of the system to match make-up air intake to the IAQ requirements of the facility. The dual path system can condition 60% less make-up than conventional systems while maintaining ASHRAE 62-89 guidelines. Tests conducted under the guidelines of DOE 2.1E show that the dual path system has the additional capability of shifting peak building energy demand out of phase with peak seasonal usage. In some locations this load shedding feature is incentivized by local utilities further reducing cost of operation.

Taken together, these features allow the equipment to achieve exceptional energy consumption reductions compared to conventional HVAC equipment.

Low Cost Installation
Pre-engineered, unitary equipment design eliminates custom composite system design and the up-front and maintenance cost of composite systems.

With a relatively small foot-print per ton, and flexible installation configurations (including in the ceiling and rooftop models), dual path equipment do not take up space that can be generating lease revenue. In most applications, equipment rooms dedicated to dual-path equipment can be eliminated.

Simple one-step system balancing shortens start-up time to further contain installation cost.

Multi-point Control Systems
Dual path systems use three types of control points within the building envelope:

1. Humidity sensors
2. Temperature sensors
3. Carbon dioxide (or IAQ) sensors

Humidity sensors located in each zone allows the equipment to accurately control humidity with the occupied space. Humidity is maintained below levels that foster the growth of mold and mildew. This enhances zone comfort and eliminates the stuffy, muggy atmosphere prevalent with commercial structures in hot and humid climates.

Temperature sensors maintain sensible heat within comfort ranges by zone.

Carbon dioxide (or IAQ) sensors activate make-up air dampers when, and only to the extent that, ventilation is required. This assures that codes are always met without the input and conditioning of excess outside air.

DESIGN CONSIDERATIONS FOR TOTAL BUILDING AIR MANAGEMENT

Maximizing system Operating Potential
Although the dual path system achieves extraordinary operating efficiencies, further efficiencies are possible when a "total building system" design is implemented. To maximize operating economies in commercial buildings, two design strategies should be employed in addition to designing to sensible and latent load:

1. Utilization of heat before it is rejected
2. Economical rejection of excess heat from the building loop

Methods of Excess Heat Utilization
Commercial buildings in general, and in hot and humid climates in particular, tend to have a heat rejection burden. Building heat generated by people, equipment and lights is stored in the building loop. This heat generally exceeds any heating requirements of the building and must be disposed of to maintain the loop at optimal equipment operating temperatures. Because heat rejection consumes energy, it is prudent to utilize excessive heat productively, rather than throw it away. By developing an integrated approach to excess heat usage, energy consumption can be reduced. Typical methods of using excess building heat include:

1. Pre-heating potable hot water for use in lavs
2. Pre-heating process water (laundry and dish washing water for examples)
3. Pre-heating make-up air (in cool weather)

Hot water generators and heat exchange units are excellent add-on choices for dual-path systems. These add-ons can often pay for themselves in reduced energy consumption. The test site integrated a water heating system into the building loop with excellent results.

Methods Of Heat Rejection
A typical method of heat rejection in commercial water source heat pump systems is through the use of an evaporative cooler (cooling tower). This method of heat rejection is an excellent

choice in applications when heat rejection is the primary building load and health issues are not a dominant concern.

In other applications, where heating and cooling loads are balanced, where ground water is readily available, or where the risk of legionella is of concern, energy consumption and equipment maintenance can be significantly reduced by replacing the cooling tower with a ground source heat exchanger. Ground source heat exchangers reject excess building heat into the relatively cool earth during the cooling season, and extract heat from the ground during heating. In hot and humid climates, it is critical that every option be implemented for utilizing building heat prior to heat rejection to contain the size of the ground loop.

In areas where seasonal heating is required, but cooling remains the dominant load, a hybrid heat rejection system can be specified. A hybrid system consists of a ground loop sized for total heat rejection, and an evaporative cooler sized to cool the building loop at night or when energy usage rates are low. This combination has a lower first cost than a ground loop sized for the entire heating and cooling load of the building, but is not as energy efficient as a ground loop for heat rejection.

Changing Role Of The System Integrator In Our Changing Times

The engineer, contractor or designer charged with designing a total building air management system using dual path equipment has the task not only of designing a system to meet the cooling needs of the commercial building, but of investigating every possible building function with the eye to controlling system operating costs. In this sense the designer acts as a systems integrator. To maximize the benefits of dual path equipment, he must fully understand that total energy usage of the building. By maximizing the use of heat collected by the building loop and optimizing the cost of heat rejection, he can significantly reduce energy requirements of the building, the burden on the local utility and the impact on the environment.

Every application has a unique set of total building management requirements. The following are suitable applications for dual path systems.

1. Supermarkets and megamarkets: Heat rejected from cases can be rejected into the building loop and used to pre-heat potable and process water. A "Green" building offers the owner an excellent public relations tool in these applications
2. Dry goods and other retail outlets: Again, "Green" is good. Zone air management and metering allows tenants full control of their retail space
3. Hotels and motels: Zoned control of humidity, temperature and positive or negative pressure maximizes guest comfort. Indoor pool rooms profit from the latent heat control afforded by dual path equipment
4. Restaurants: Air quality and pressurized zones the dining experience. Kitchen heat can be used to pre-heat process water.
5. Health care facilities: These facilities benefit from the precise control of latent and sensible heat offered by dual path equipment. Isolation rooms can be pressure controlled to prevent cross-contamination
6. Schools: Flexible equipment design and placement frees up floor space for classrooms. Make-up air is provided only when classrooms are in use. Equipment maintenance can be performed by unskilled personnel to contain the cost of maintenance within budget. The option of zero ODP ("Green") refrigerants is an appealing public service feature popular with school boards.

Partnering With the Local Utility Company

Today's utility company often has a stake in the design and construction of commercial HVAC systems. Recently, local electric utility providers have been anxious to partner with owners, designers and engineers in installing dual path system and ground loop heat rejection systems. The local utility often provides incentive for selecting a system that maximizes the energy savings potential of the building or can be shown to provide load shedding features.

CONCLUSION

Hot and Humid climates pose particular problems for the HVAC system designer that conventional and composite systems cannot entirely solve.

Dual path systems, monitored in 1995 in actual installations, show great potential for meeting the indoor air quality and comfort requirements of commercial buildings in southern states and coastal regions, while simultaneously controlling first cost and containing operating and maintenance costs.

Dual path equipment, shown to be particularly cost-effective in new construction, is flexible for most applications, either installed as stand alone units, or in combination with other HVAC and refrigeration equipment.

APPENDIX A
CASE STUDY ANALYSIS

CASE STUDY OVERVIEW

The project described in this paper is a 200,000 square foot supercenter located in Moore, Oklahoma. Within the building envelope are contained a complete super market and a retail store with a full range of household goods, dry goods and other non-perishable household consumables.

All space conditioning, refrigeration and water heating systems are integrated onto a single building water loop. Excess loop heat is rejected by means of a cooling tower.

EXTRACTS FROM CASE STUDY

DOE 2.1 E Study: Proto Vs Moore, Oklahoma
Proto 188 #40-250.02

According to our building simulations, the Moore, Oklahoma Supercenter will use an estimated 22.6% (1,614,287 kWh/year) less than a prototypical base store. Utilizing the (local utility) rate structure this would result in a savings of approximately $87,573.89 per year. . . The electrical energy savings for the major areas of energy savings are as follows:

Description	Base kWh/Yr	Moore, OK kWh/Yr	Savings kWh/Yr
HVAC	3,538,554	2,738,732	799,822

Department of Energy program DOE 2.1E was used to evaluate the base (prototype) store and the environmental store in Moore, Oklahoma*. The program uses an average year (computed from a 30 year weather data base) to determine annual energy usage.

The following is an outline of the differences between the base (prototype) store and the Moore, Oklahoma store.

Description	Base	Moore, OK
Cooling	RTU- Air Cooled	Heat Pumps-water Cooled
Heating	RTU-Electric	Heat Pumps - Water Loop and Electric
Dehumidification	Desiccant - Gas Fired	Low Temp DX-Water Cooled

Three items identified as the largest electrical building loads have been reduced by implementing the following changes:

1. Dimming System *(the description that follows in the original is not pertinent to this paper and has been omitted here)*

2. Water Cooled Heat Pumps - HVAC energy has been reduced by 22.6% (799,822 kWh/Year). This was accomplished by using water-cooled equipment and connecting the refrigeration system with the heat pump units. Water cooled equipment operates more efficiently than air cooled equipment, and all the equipment used on the Moore, Oklahoma store was designed to have high efficiencies. The piping connection between the refrigeration system and heat pump units allows the heat rejection of the refrigeration to be transferred to areas requiring the heat.

3. Water Cooled Refrigeration System *(the description that follows in the original is not pertinent to this paper and has been omitted here)*

** After almost one year in service, operating costs for equipment in this application were actually less than projected by the DOE study. For more information about this case study, contact the Electric Power Research Institute, Inc. (EPRI) Palo Alto, CA.*