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APPLICATION BULLETIN
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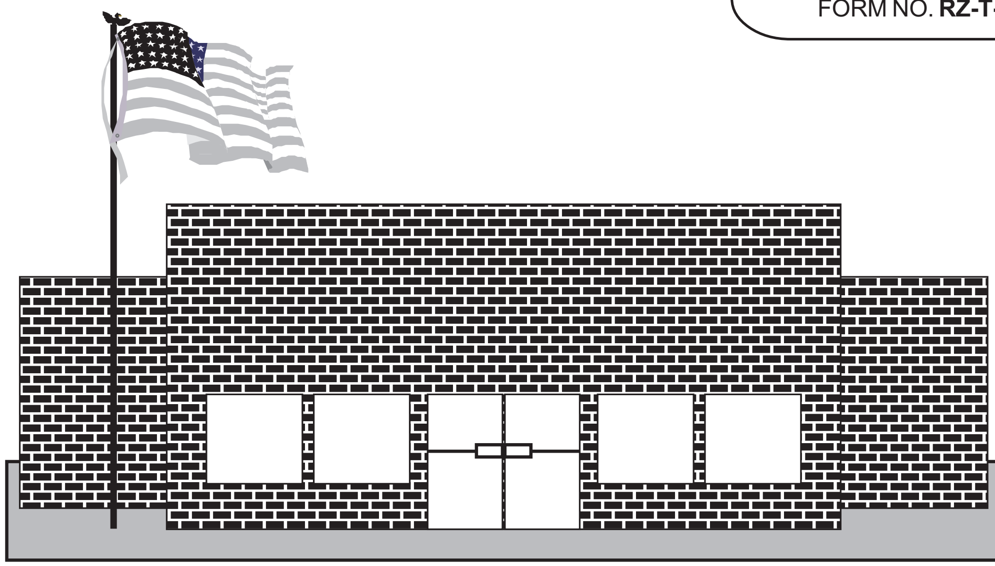


Desiccant Based Total Energy Recovery Systems for Schools, Public Buildings, and Offices

PREFACE

Maintaining a desirable indoor air quality in schools, public buildings and offices should be a top priority. It impacts the learning process as well as the comfort and health of the students, teachers, workers and all occupants. Facilities designed to comply with the ASHRAE 62-1989R IAQ Standard require high outdoor air quantities. A large quantity of continuous outdoor air typically cannot be accommodated by the standard packaged HVAC equipment used by most schools. Unacceptable high moisture conditions result during the cooling season while very low moisture conditions occur during the heating season. To avoid these conditions, many schools are forced to cycle the outdoor air supply with the heating/cooling temperature controller, negatively impacting the health and comfort of the building occupants.

This report demonstrates how desiccant based total energy recovery preconditioning allows conventional HVAC systems to accommodate ASHRAE 62-1989. Facilities incorporating the technologies are shown to be cost effective, energy efficient and offer year round humidity control. The added cost of the total energy recovery approach is weighed against the resulting IAQ benefits. A study of eight schools, all previously experiencing serious IAQ problems, confirmed that retrofitting their existing HVAC systems with total energy recovery preconditioners to comply with ASHRAE 62-1989 resulted in a complete and lasting resolution. These and other findings presented by this investigation (see Appendix) strongly support the current ASHRAE 62-1989 recommendation of 15 cfm/student of outdoor air, supplied on a continuous basis, while maintaining space moisture conditions between 30% and 60% relative humidity (RH).

INTRODUCTION

There are many reasons why indoor air quality (IAQ) should be considered a top priority in the school environment. Children are still developing physically and are more likely to suffer the consequences of indoor pollutants. The number of children suffering from asthma is up 49% since 1982 according to the American Heart and Lung Association. Children from birth to age 10 have three times as many colds as adults (Tyrrell 1965). School facilities, by design, are densely populated, making the task of maintaining an acceptable IAQ more difficult than many other types of facilities. The sole purpose of a school facility is to foster the learning process. Most individuals have experienced drowsiness, lack of concentration or headaches in a classroom or auditorium environment and understand the impact these symptoms have on comprehension and motivation. A 1996 General Accounting Office (GAO 1996) study reported that IAQ problems are experienced by approximately 20% of all public schools surveyed.

In practice, there has been resistance to following the best available blueprint for ensuring acceptable IAQ (ASHRAE Standard 62-1989). The perception is that designing to the standard requires a significant increase in both project first cost and operating cost. Design engineers are usually compelled to work with very tight budgets and therefore utilize inexpensive, packaged HVAC equipment that is not designed to handle the high volumes of outdoor air required for a typical classroom environment. There is a legitimate concern that conventional system approaches will result in humidity control problems that may negate benefits provided by increased ventilation. In short, a common perception might be that the cost associated with accommodating ASHRAE 62-1989 is high while the resultant benefits are low.

Experience gained from many facilities that have been designed with desiccant based total energy recovery preconditioning to accommodate ASHRAE 62-1989, and interviews directly with design engineers and building occupants, actual IAQ research conducted on schools that experienced serious IAQ problems and a review of existing research relating IAQ to the school environment, all considered by this report, strongly suggest the opposite.

See Appendix for additional documentation.

WHY IAQ PROBLEMS ARE COMMON IN SCHOOLS AND OTHER FACILITIES

IAQ Challenge to Traditional HVAC Equipment

Both research summarized in the Appendix section and actual field experience (presented in detail by the following sections) support the need for continuous ventilation in accordance with ASHRAE 62-1989 while maintaining the space RH between 30% and 60% RH. IAQ problems result in schools when the HVAC systems are not able to meet the design criteria.

Most facilities utilize standard packaged heating and cooling equipment, designed to provide inexpensive, efficient heating and cooling, with minimal outdoor air. This type of equipment is not designed to handle the continuous supply of increased outdoor air necessary to comply with the ASHRAE 62-1989 guidelines in a school facility. As a result, buildings designed with only conventional packaged HVAC equipment are likely to experience IAQ problems due to the following limitations.

Increased Outdoor Air Quantities

Increased quantities of outdoor air will significantly increase the operating cost of a conventional HVAC designed without total energy recovery system. In a typical school classroom environment designed for 28 students and a teacher, the outdoor air ratio is typically 36%. This is based on providing 15 cfm/occupant and a three ton load using 400 cfm/ton. Since conventional packaged equipment has been designed to accommodate approximately 20% outdoor air on an intermittent basis, increasing the outdoor air ratio to 36% can result in unacceptable high space humidities for extended periods of time. In addition, this increased outdoor air may create load problems and even equipment failure.

During the heating season, these high outdoor air ratios can result in the distribution of very cold air when the space heating load is satisfied and the heating source is deactivated. This problem is often overcome with the use of dedicated heating equipment of a more specialized nature, such as Reznor® packaged heating/outside air units with stainless steel heat exchangers and ductstat temperature control. Very low space RH conditions are also common (10-20% RH) during the heating season since the high air exchange rate overwhelms the latent load generated by the occupants and dry outdoor air is heated to maintain space conditions.

Continuous Supply of Outdoor Air

Much of the discussion concerning the impact of the ASHRAE 62-1989 standard has been focused on the cfm/person recommendations. The need to provide the outdoor air continuously provides an even bigger challenge to packaged HVAC equipment than does the increased outdoor air ratio.

On mild, humid days (part load conditions) the packaged HVAC equipment quickly brings the classroom to the temperature set point then cycles off the cooling coil. As raw outdoor air is introduced into the space, the indoor humidity level climbs. Eventually the space thermostat calls for cooling. By this time, the mixed air condition supplied to the coils is elevated in moisture content. This results in a high dew point condition leaving the cooling coil. The space temperature is still maintained but humidity control is lost resulting in conditions likely to promote microbial and other moisture related IAQ problems.

Avoiding High Space RH

In addition to the performance limitations of the conventional HVAC system discussed previously, two other design issues have a significant impact on the resultant indoor air RH. They are the revised ASHRAE dewpoint weather data and evaporation of condensed moisture from a cycled DX cooling coil.

Impact of New ASHRAE Design Dewpoint Data

The design weather data used by most engineers does not accurately reflect the design latent load (i.e. moisture content) of the outdoor air. This resulted from the manner in which the raw weather data has been reported to the design community: configured into dry bulb BINs with corresponding mean coincident wet bulb temperatures. This method provides a good representation of the design sensible load associated with the outdoor air to a classroom by approximately 20%.

New ASHRAE dewpoint design data which more accurately reflects the latent loads associated with the outdoor air is now available (Colliver et al. 1996) and is scheduled to be printed in the 1997 ASHRAE Fundamentals.

Evaporation of Condensate from a Cycled DX Cooling Coil

Henderson et al. (1996) and Khattar et al. (1985) confirmed a condition often observed in the field where the actual moisture removed by a conventional HVAC system is significantly less than that anticipated based on published performance data. The research shows how moisture condensed on a DX coil evaporates back into the supply air stream when the coil is cycled off and the fan continues to operate. Henderson (1990) documented that the actual latent removal can be reduced to less than 50% of the unit's rated capacity under part load and continuous fan operating conditions.

Avoiding Low Space RH

Experience has shown that even in the southeastern climates, continuously providing 15 cfm/person of outdoor air to a typical classroom during the heating season can result in space relative humidities well below 30% for extended periods of time. For northern climates this would result in indoor relative humidities below 25% throughout much of the heating season, and frequently below 20%. Although the benefits of humidification are obviously based on the supporting research, few schools appear willing to allocate the funds or maintenance manpower to provide it.

TOTAL ENERGY RECOVERY

Meeting the Challenges with Total Energy Recovery

Total energy recovery systems are now routinely coupled with packaged HVAC equipment to accommodate the increased outdoor air requirements (ASHRAE 62-1989R). This approach has proven as an effective and economic way to avoid IAQ problems in school facilities.

Total energy recovery can be applied in various system configurations. The appropriate approach is guided by climate, architectural design, DX or chilled water, whether it is retrofit or new construction and budget constraints.

Total Energy Recovery: What it is

Total energy recovery wheels or "enthalpy wheels" are unique in that they typically recover 50-80% of the total energy (heat and moisture) contained within the air stream being exhausted from a facility. Today's state of the art total energy wheels utilize a desiccant laden, fluted substrate which rotates between the air stream being exhausted from a facility and the clean, outdoor air stream.

Two very important and basic facts that apply to all energy wheels are as follows:

1. The substrate serves as the heat sink to transfer the sensible energy. The effectiveness is directly dependent on the total mass of the wheel. (Note: the desiccant adds to the mass but the primary purpose is not sensible energy.)
2. The desiccant material in the substrate (for some designs - on the substrate) transfers the latent energy. The effectiveness is dependent on the type of material and the concentration. (Note: some desiccants are applied to the substrate. The wheel used in Reznor product used a product that has desiccant embedded for superior transfer of latent energy.)

This "adsorbent" desiccant transfers the moisture in its vapor phase. As a result, the surface of the transfer matrix remains dry in most applications.

Desiccants are porous crystals that have an enormous internal surface area. They are able to "pull" water vapor out of the air based on the vapor pressure differential that exists between the outdoor and indoor conditions.

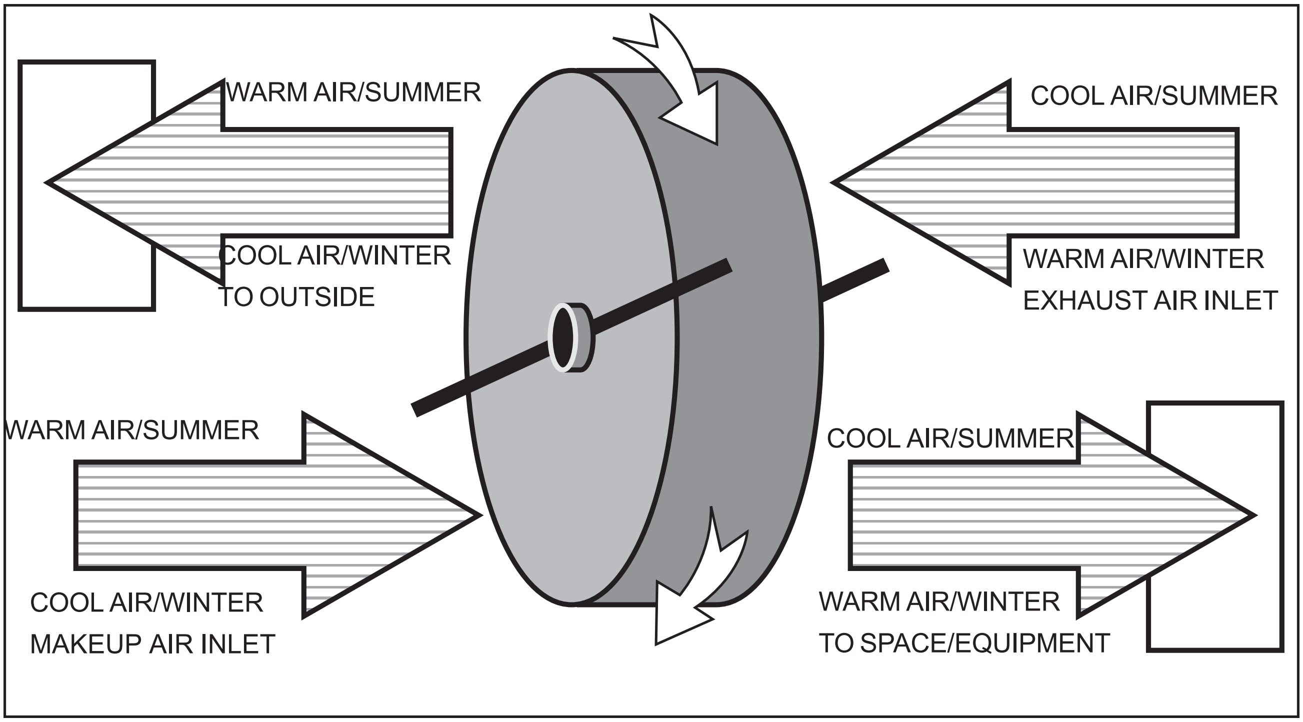
Total Energy Recovery: How it Works

During the cooling mode, one half of the wheel absorbs heat and moisture from the incoming outdoor air. As a result cooler, dryer air leaves the wheel and is introduced to the cooling coil or space. The air exhausted from the space picks up the heat and humidity temporarily stored in the second half of the wheel, and sends it outdoors.

In the heating mode the process is reversed. Cold, dry outdoor air enters the total energy wheel. As it does, it is preheated and humidified. The exhaust air leaving the space is not only cooled but dehumidified, thereby avoiding saturation and significantly reducing the likelihood of frost formation, providing a key advantage over sensible only recovery alternatives.

As stated earlier, the quality and quantity of the desiccant used for a given total energy recovery wheel product determines the latent recovery effectiveness. Effective latent recovery is very important. In many climates it is the outdoor air latent load, not temperature, that taxes the performance of conventional cooling equipment. In addition, the dehumidification and humidification energy savings are typically greater than savings attributable to temperature only recovery. It is also advantageous to recover latent energy as effectively as sensible energy so that full recovery can be realized at the lowest possible outdoor air temperature without the need of parasitic preheat or bypass to avoid frost formation.

Another issue that should be addressed is that of reintroduction of unwanted compounds from the exhaust air



into the incoming fresh air stream. The desiccant will "absorb" molecules depending on

- the size of the molecules,
- the attraction for that molecule and
- the relative concentration of the molecule.

You might hear references to 3A and 4A wheels. A 3A sieve has an average pore size of 3.2 angstroms and a 4A sieve has an average pore size of 3.8 angstroms. While some unwanted molecules might be close to the size of a water molecule, most are larger. The wheel used by the Reznor ERSA product is a 4A molecular sieve type. It can be argued that a 4A desiccant will allow faster transfer of certain compounds than a 3A desiccant. Based on molecular size alone this could be true. In an anhydrous adsorption process this would be true although the high partial pressure of water typically would create a condition resulting in negligible adsorption of contaminated molecules.

Practical application and laboratory test have proven that in airstreams where moisture is present, (typical most applications) the desiccant has such a high affinity for the more polar and smaller water molecules and due to the higher partial pressure of water (compared to other molecules) the adsorption of unwanted compounds is negligible.

In other words, in most applications for this product, transfer of unwanted compounds to the incoming air stream should not be a problem. If you feel you have a very critical application, then we would suggest further exploration and looking at our more custom line of energy recovery products.

Benefit of Preconditioning: No Summer - No Winter

In nontechnical terms, the effect of adding a total energy recovery wheel to the mechanical design of a facility is that winter and summer cease to exist from the perspective of the building's HVAC system. The recovery of both temperature and moisture isolates the building from extreme weather conditions, delivering more moderate conditions to the HVAC system year around.

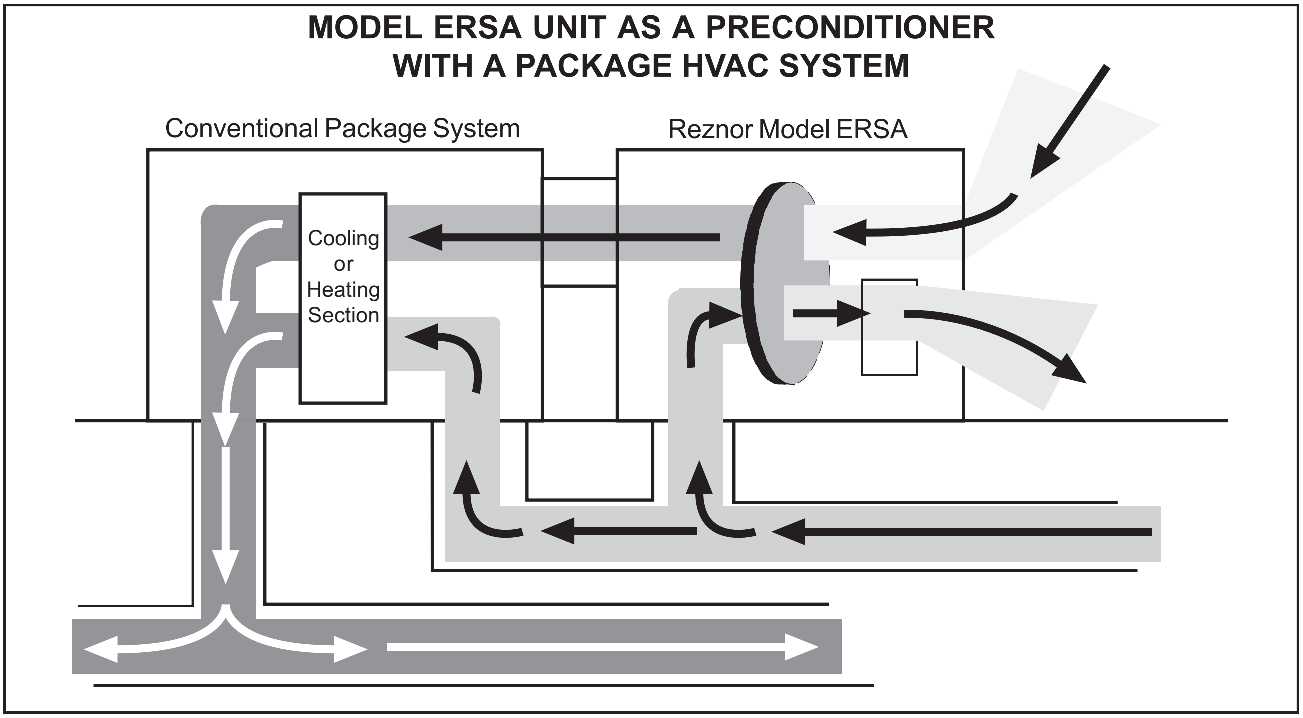
Consider a psychometric plotting of a three ton cooling unit for a typical application, with 15% OA for a single classroom with 30 students. The OA condition is 97/76 db/wb and the RA is 75/62.5 db/wb. The mixed air condition (MA) has an enthalpy of 29.92 or a total cooling requirement of 39,150 BTUH at 1,200 total air volume.

Then compare, a psychometric chart plotting with the same conditions as previous except using 40% OA (outdoor air) with a total energy recovery on the outdoor air then blending the balance of the return air to give the MA condition. The enthalpy with this condition is 29.28 BTU/pound of dry air or a total cooling requirement of 35,694 BTU/HR.

It is noted that using the total energy recovery unit for the outdoor air of 40% of total air volume for the classroom has actually reduced the required load by approximately 4,000 BTUH. This approach has also given a positive control over the humidity levels for the space.

With the varying conditions of the ambient, you will find that the total energy recovery unit function will eliminate the entering coil swings to a deviation less than 5%, therefore creating a constant coil condition.

The total energy recovery unit is just as effective during



the winter months as in summer with the added benefit of adding moisture to the outdoor air. This reduces the amount of moisture that will need to be added to maintain the minimum indoor relative humidity levels.

CONCLUSION

Desiccant based total energy recovery preconditioning has been proven to be a cost effective, energy efficient and reliable way to allow conventional HVAC system design to accommodate the recommendations made by ASHRAE standard 62-1989 (R). Doing so has been shown in actual practice to provide a desirable indoor air quality which enhances the learning process in school facilities and productivity and comfort in other facilities.

Refer to our product literature regarding the sizing of preconditioners. Reznor products (ERSA) are pre-engineered to take the "guesswork" out of product selection. These products are generally applicable to solving ventilation and outdoor air problems for many different types of buildings.

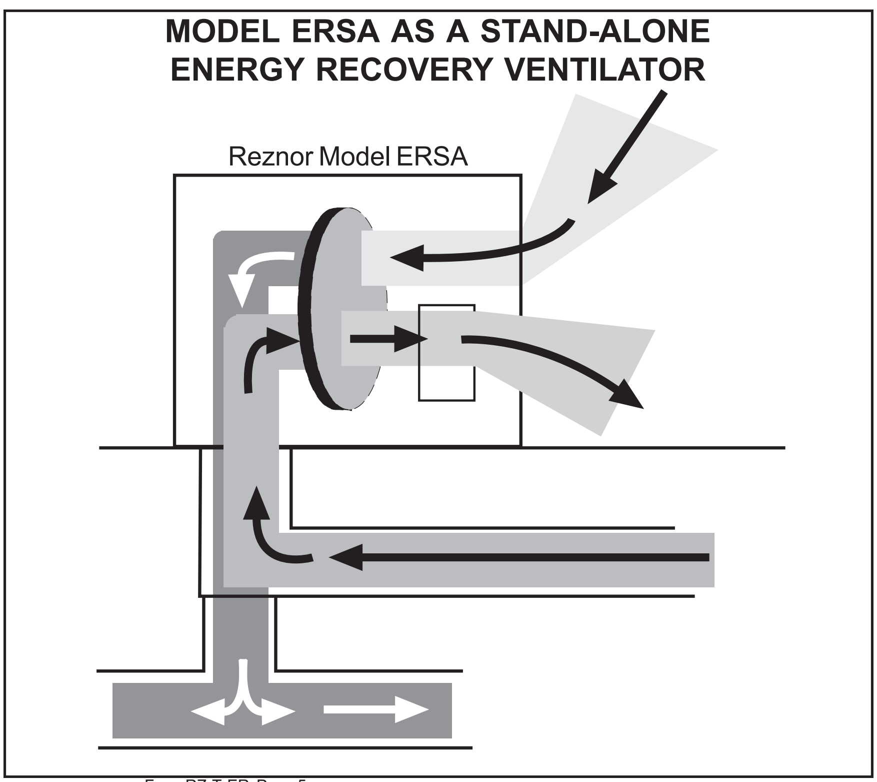
For more information please contact your local Reznor distributor or local Reznor Factory Representative at 1-800-695-1901.

APPENDIX -

ADDITIONAL INFORMATION

BACKGROUND SUPPORT

The Occupational Medicine Division at Armstrong National Laboratory conducted IAQ surveys of 46 government buildings, involving thousands of occupants between the years of 1985 and 1992. This work provided the basis for specific recommendations made by



Armstrong Laboratory regarding indoor air quality investigations and occupational health issues. The three most frequent causes of unacceptable IAQ were reported to be: inadequate design and maintenance of air handlers, shortage of fresh air and lack of humidity control (Armstrong 1992). A similar NIOSH study recognized inadequate ventilation as the source of IAQ problems in 52% buildings surveyed.

Most school facilities are designed with very simple mechanical systems, typically allocating packaged HVAC units on a room by room basis. As a result, maintenance is limited mainly to filter replacement (which also impacts the ventilation rate). Projecting the findings of Armstrong Laboratories and NIOSH to school facilities would suggest that the majority of IAQ problems experienced would occur as a result of inadequate outdoor air and/or lack of humidity control.

A significant body of research exists that evaluates the relationship between ventilation rate, high indoor humidity levels and low humidity levels and the physiological effects on building occupants. This section provides a summary of this research which supports the recommendations set forth by ASHRAE 62-1989 for school facilities.

Outdoor Air Ventilation Rates

Downing and Bayer (1993) investigated the relationship between ventilation rates and IAQ in the classroom environment. The study confirms that 15 cfm/student is required in order to maintain CO2 concentrations below 1000 ppm. The study recommends that all classrooms, both new and existing, be provided with at least 15 cfm/student of outdoor air on a continuous basis during school session. It also reports that the resultant concentration of volatile organic compounds (VOCs) exceeded 1,000 mg/m^3 when 5 cfm/student was provided on a continuous basis, an indication of potential indoor air quality problems (Tucker 1986, 1990).

An extensive study of Swedish office spaces conducted by Sundell et al (1991) reports a very direct relationship between general sick building syndrome (SBS) symptoms, which include “fatigue, feeling heavy headed, headache, nausea/dizziness and difficulty concentrating” and outdoor air ventilation rates. Burge et al (1991) concluded that increased ventilation decreases the rate of viral respiratory infections. Bayer and Downing (1991) investigated a 30 story office building to correlate ventilation rates and indoor contaminant concentrations and concluded that a healthier building with increased energy conservation can be achieved by using total energy recovery preconditioning.

The Armstrong “Occupational and Environmental Health Directorate” (1992) concludes that carbon dioxide (CO^2) concentrations in excess of 600 ppm cause significant physiological effects, listed as fatigue, drowsiness, lack of concentration and sensations of breathing difficulties. Rajhans (1983) and Strindehag et al. (1990) also recommend ventilation necessary to maintain 600 ppm of CO^2. Approximately 40 cfm/person of outdoor air is required to maintain a CO^2 concentration of 600 ppm ion an occupied space (in lieu of 15-20 recommended by ASHRAE).

High Relative Humidity in Occupied Spaces

The Armstrong Laboratory (1992) study sighted microbial contamination in nearly 50% of the buildings investigated. It stated that based on its findings, carpet, curtains, furniture, etc. can absorb enough moisture at space humidities greater than 65% to promote microbial growth. Its final report recommends that buildings be maintained between 40% and 60% RH.

Baughman and Arens (1996) summarize numerous health related effects associated with high and low indoor RH including mycotoxins and VOCs produced by fungi.

Bayer et al (1995) investigated schools with complaints of rashes and respiratory illnesses. The investigation focused on microbial growth which was identified in all cases. It concluded that many of the airborne VOCs appeared to be microbial in origin. Bayer and Downing (1992) reported on three schools that were investigated and found serious humidity problems, even with intermittent outdoor air being supplied to the occupied space.

Low Relative Humidity in Occupied Spaces

In 1964, (Ritzel 1966) and in 1970, (Sale 1972) studies were conducted in controlled populations of kindergartens to determine the relationship between respiratory illness and space RH. In both studies, in the schools where the humidity was increased with humidifiers, the absenteeism was 40% to 50% lower than in the unhumidified schools. They also reported a decrease in colds, sneezing, sore throats and fever experienced by the children in spaces humidified in the winter season.

The Sale study, which investigated approximately 500 kindergarten students, investigated the impact of humidification in the home in conjunction with humidification in the school.

Group 1: 39 children, humidification at home and at school

Group 2: 101 children, humidification at school only

Group 3: 95 children, humidification at home only

Group 4: 281 children, no humidification

The Sale study reported the rate of absenteeism as follows: Group 1 at 1.3%, Group 2 at 3.0%, Group 3 at 5.1% and Group 4 at 7.1%.

In 1960, and again in 1970-71, Green (1974) compared the absenteeism due to all causes for a total of 18 schools, some humidified to greater than 25% RH and the others not humidified, involving approximately 4800 students. Green reported a statistically significant lower absenteeism for the humidified schools. Green investigated 11 years of records for the schools and found that in every year absenteeism was lower in the humidified schools. Similar studies involving army recruits (Gelperin 1970-71) and hospital staff (Green 1974-76) showed a drop in absenteeism with humidified spaces of 14% and 22% respectively.

In Arundel et al. (1986), a study concluded that influenza virus cultivated in human cells had the highest survival rate when exposed to low relative humidities (20%), which fell to a minimum at between 40% and 60% RH, and increased again after exposure to high humidity (70-80%). A plot of the morbidity from colds and low indoor humidity has been shown by Hope-Simpson (1958) to have a "high correlation".

The Armstrong Laboratory (1992) sighted low relative humidity as a problem in 39% of the buildings investigated listing associated physiological effects as dry eyes, nose and throat, sinus and tracheal irritation, itchy skin and the inability to wear contact lenses comfortably. Its report stated that low relative humidity also contributes to respiratory illness by weakening the defense provided by the mucous membrane in the body's air ways.

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REZNOR PRODUCT LINE

Reznor products include an extensive line of heating, cooling and ventilating systems, using gas, oil, hot water/steam or electric heat sources. Reznor equipment is designed for the commercial/industrial market. A national network of sales representatives and distributors are trained in Reznor products and possess technical tools to help you determine the best equipment for your particular application. Please feel free to contact these specialists when industrial heating and cooling is being considered.

NOTICE:

This bulletin is intended for general information only. In all cases, local and national mechanical and electrical codes must be followed. Also refer to and abide by the manufacturer's specific installation, operation and maintenance instructions for all equipment. Installation and service of equipment should be by licensed, qualified professionals only.

IMPORTANT:

Read manufacturer's installation, operation and maintenance manuals thoroughly regarding all INSTRUCTIONS, CAUTIONS, WARNINGS AND NOTICE STATEMENTS before specifying, installing, operating or servicing equipment.

WARNING

Improper specification, installation, operation or maintenance of equipment may cause:

- severe personal injury or death and/or
- conditions that may result in property damage.

The following precautions MUST be observed:

- Proper venting, gas and electrical supply according to national and local codes.
- Proper application, setup and operation of this product, as well as all other building equipment, to eliminate buildup of contaminants in the conditioned space.
- Proper environment/atmosphere or application to avoid fire or explosion from hazardous atmospheres containing flammable vapors or combustible dust.
- Specification of the proper equipment for the particular application.

SUMMARY

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