# AIR-TO-AIR HEAT EXCHANGERS FOR ENERGY EFFICIENT VENTILATION OF "TIGHT" STRUCTURES

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Energy conservation could be hazardous to our health.

The quality of indoor air has increasingly become a major concern for architects, contractors, facility engineers, utilities, as well as occupants of offices, schools and homes.

In the interest of conserving energy, "tighter" structures are being designed and constructed that reduce the flow of fresh air.

Recent laboratory studies have shown that insufficient air changes can lead to conditions, which are not only unpleasant, but unhealthy, due to the increased levels of indoor pollutants and also, can damage the structure through increased indoor moisture content.



Dr. Phillip R. Taylor of the United States Center for Disease Control, Atlanta, Georgia, currently assigned to the New York State Health Department, in his recent investigation of the Itel Corporation in Port Washington, Long Island, where 150 employees suffered such symptoms as nausea, lethargy, swollen eyes and light headedness, concluded, "Indoor air pollution is the mystery illness".

Dr. Taylor stated these symptoms were caused by a combination of slightly elevated levels of many different pollutants.

No single compound was found that explained all the symptoms. It was basically a stale air problem. The building's ventilation was inadequate. Sample tests in the 35,000 $ft^2$ building revealed higher than normal levels of carbon monoxide, carbon dioxide, formaldehyde, hydrocarbons, and "dirtiness" in the air, as well as less of a percentage of oxygen in the interior air as that found outdoors, according to Dr. Taylor. He continued, the amount of fresh air introduced into the building's tight envelope was less than half of the recommended minimum.

A two-year, $700,000 study to determine the effects of air infiltration rates on energy use and indoor air quality of residential buildings has been launched by the Electric Power Research Institute (EPRI).

The study, which is being conducted through EPRI's contractor, Geomet Incorporated, involves the monitoring of two new unoccupied, single-family homes in suburban Washington. Arvo Lannus, EPRI Program Manager, stated, "We want to examine quantitatively the role that pollutant sources, as well as weatherization practices, play in determining indoor pollutant concentrations".

Bonneville Power Administration (BPA), an arm of the Department of Energy (DOE), has been promoting higher insulation levels in Pacific Northwest homes. BPA, concerned of the health hazards of super-tight homes, will conduct public meetings to discuss the ramifications of an environmental impact statement (EIS) required by law.

In a brochure mailed to homeowners, the agency said, "Reducing a home's air exchange rate by sealing air leaks also has the side effect of increasing the concentration of various air pollutants found indoors. Installing home-tightening measures does not cause indoor air pollution. It can aggravate existing problems. Some of the indoor pollutants are irritating to the respiratory system and some are capable of causing cancer".

A malaise, called "tight-building syndrome", may be the problem, wrote Sheila Sobel Moramarco in the American Health Magazine in an article titled, "Does Your Office Make You Sick?".

Many, many other publications and editorials have been written and many awareness sessions have been held to provide the designers and the public with information on indoor contaminants, their source, effect and control.

The troublesome pollutants created by this trend to energy savings are located and identified as follows in residential structures. Similar pollutants are present in Commercial, Institutional structures.

1. Basement and laundry room area
   (a) Benzene and carbon tetrachloride from spot cleaners
   (b) Carbon monoxide and nitrogen dioxide from gas dryer
   (c) Chlorine fumes from bleach
   (d) Formaldehyde from soaps, plywood, plastics
   (e) Lye from drain cleaner
   (f) Radon from concrete walls



2. Living room area
   (a) Benzopyrene from tobacco smoke
   (b) Carbon monoxide from tobacco smoke
   (c) Formaldehyde from carpets, drapes, furniture, plywood in sub-flooring and paneling, tobacco and wood smoke
   (d) Nitrogen dioxide from wood and tobacco smoke
   (e) Radon from brick or stone fireplace
   (f) Napthalene and paradichlorobenzene from mothballs in closet

3. Kitchen area
   (a) Ammonium hydroxide from window cleaner
   (b) Carbon monoxide from gas stove
   (c) Formaldehyde from gas stove, particle board in cabinets, curtains, wallpaper, plastic appliances
   (d) Hydrogen cyanide from gas stove
   (e) Nitrogen dioxide from gas stove
   (f) Potassium hydroxide from spray oven cleaner
   (g) Propane, butane, nitrous oxide from aerosol sprays
   (h) Sodium lauryl sulfate from carpet shampoo

4. Bathroom area
   (a) Aluminum chloride from deodorant
   (b) Formaldehyde from carpet, curtains, cabinet, shampoo, toothpaste, disinfectant
   (c) Hydrocarbons from aerosol sprays
   (d) Radon from water in sink and tub
   (e) Vinyl acetate polymer from hair spray
   (f) Trichloroethylene in shoe cleaner

5. Workshop and garage area
   (a) Acetone and hydrocarbons from paint thinner
   (b) Insecticide fumes from yellow pest strips
   (c) Lead from gasoline
   (d) Methylene chloride and phenols from paint stripper

(e) Toluene from spray paint
(f) Carbon monoxide from auto exhaust

Other contributions to indoor pollutants include kerosene heaters, home fireplaces, insulation and air conditioning systems.

It would appear that your choices are either to expire from indoor air pollution or the high cost of energy.

In 1981, an editorial in the Journal of American Medical Association called for a temporary halt to our energy conservation programs until we know more about the risks of indoor pollution.

Investigation and studies have concluded that ventilation dilution of the contaminants is a simple and practical solution.

Introduction of an energy efficient system, which not only controls the ventilation, but in addition, recovers wasted heat, is the air-to-air heat exchanger.

In Sweden and Japan, such mechanical heat exchangers are mandated for new energy efficient housing. In the U.S.A., specifically California, legislation has been written which mandates heat exchangers for certain type structures.

There are three basic types of air-to-air recovery systems available -- the rotary regenerative wheel, the coil loop and the plate heat exchanger.

The plate-type air-to-air exchanger is ideally suited for Commercial, Institutional and Residential HVAC ventilation applications, since it requires low maintenance (no moving parts), easily packaged into a compact, lightweight system and more importantly, has little to no cross contamination of air streams, depending on design.



ROTARY AIR-TO-AIR ENERGY EXCHANGER. The rotary air-to-air energy exchanger, popularly called a heat wheel, is a revolving cylinder, filled with an air permeable medium with a large internal surface area for intimate contact with the air passing through it. Adjacent supply and exhaust airstreams each flow through half the exchanger in a counterflow pattern. Media material may be selected to recover either sensible heat only or total heat (sensible heat plus latent heat).

Sensible heat is recovered (transferred) as the medium picks up and stores heat from the hot airstream and gives it up to the cold one. Latent heat is transferred as the medium: (1) condenses moisture from the airstream having the higher humidity ratio (by means of absorption for liquid desiccants and adsorption for solid desiccants), with a simultaneous release of heat; and (2) then releases the moisture through evaporation (and heat pick-up) into the airstream with the lower humidity ratio. Thus, moister air is dried while drier air is humidified. In total heat transfer, both sensible and latent heat recovery processes take place simultaneously.

Average effectiveness values for sensible and total heat exchangers lie in the 70 to 85% range for equal supply and exhaust air mass flow rates and usual exchanger face velocities.

Cross contamination or mixing, of air between supply and exhaust airstreams is a physical process that occurs in all rotating energy exchangers through two mechanisms -- carryover and leakage. Carryover results as air in each airstream is entrained within the volume of the rotating medium and carried into the other airstream. Leakage occurs as a result of different static pressures in the two airstreams, which drive air from a higher to a lower static pressure region.

COIL ENERGY RECOVERY LOOP. The coil energy recovery loop system utilizes extended surface, finned-tube water coils placed in the supply and exhaust airstreams of a building or process. The coils are connected in a closed loop via counter-flow piping and an intermediate heat transfer fluid of water (typically) or a freeze preventive solution is pumped through the coils.

This system allows transfer of energy from the warmer airstream to the cooler airstream. In a typical comfort-to-comfort application, the system is seasonally reversible -- the supply air will be preheated when the outdoor air is cooler than the exhaust air and precooled when the outdoor air is warmer. This system operates generally for sensible heat recovery.

As with other air-to-air energy recovery equipment, measures must be taken to prevent potential freezing of exhaust air condensate. A dual purpose, three-way temperature control valve is used to prevent exhaust coil freeze-up. The valve is controlled to maintain an entering solution temperature to the exhaust coil of not less than $-1^{\circ}C$ (30F), accomplished by bypassing some of the warmer solution from the supply air coil. The valve can also ensure that a prescribed leaving air temperature from the supply air coil is not exceeded for those applications where the energy recovered must be limited.

The heat recovery loop is primarily a heating device. Since it cannot transfer moisture from one airstream to another, the system is primarily used to recover sensible heat (i.e., preheat incoming supply air).

The supply air temperature for most applications can typically be increased by 60 to 65% of the temperature difference between the two airstreams.

Complete separation of the airstreams eliminates the possibility of cross contamination between supply and exhaust airstreams.



Coil energy recovery loops normally operate with a minimum amount of required maintenance. The only moving parts are the circulation pump and the three-way control valve. However, the following items must be considered to assure optimum operation: air filtration, cleaning of the coil surface and periodic maintenance of the pump and valve.

THE HEAT PIPE. This device is a special case of the closed loop coil system. It depends upon evaporating and condensing of a secondary fluid, usually freon or water, to transfer the energy from a coil in one gas stream to a coil in another gas stream. The secondary liquid is hermetically sealed in a number of tubes which are finned and extend into the opposing gas streams.

The advantage of the heat pipe is its configuration and its relative ease with which it is fitted into a system.

It, along with the coil loop, is the least efficient of the energy recovery devices (50 to 60 percent) and is medium to high in cost. It normally has 11 to 14 fins per inch, so it is also prone to fouling. It requires tilting the device so that the condensing heat transfer liquid will run back to the evaporating side. Therefore, a mechanically operated tilt device must be used for both winter and summer HVAC usage. This requires flexible connections between it and the duct work.

FIXED PLATE EXCHANGERS. Fixed surface plate exchangers can be broadly classified into two categories: (1) the pure-plate heat exchanger, consisting of only primary heat transfer surface; and (2) the plate-fin heat exchanger made up of alternate layers of separate plates and interconnecting fins. The pure plate exchanger is usually of a counterflow design, whereas the basic plate-fin exchanger is a crossflow design with combinations sometimes arranged to approach a counterflow unit. Counterflow provides the greatest temperature difference for maximum heat transfer, but crossflow can sometimes give more convenient air connections. The typical plate exchanger transfers sensible heat only, except when the temperature of one airstream is low enough to cause condensation in the opposing airstream. Since it uses no secondary heat transfer medium, such as water or refrigerant, its temperature range is the broadest of all air-to-air energy recovery equipment.

One of the advantages of the plate exchanger is that it is a static device which can be built with little or no leakage between airstreams -- depending on temperature, type of construction and the assembly method of modules. Some of the units are built with a continuous sheet of metal, formed to produce two divided air passages, some with sheets formed and welded, and some with tubes rolled into crown sheets similar to the construction of fire-tube boilers.

The pure-plate heat exchanger can achieve a high recovery sensible heat effectiveness because it is a device with only primary surface area and therefore, does not depend on fin effectiveness to enhance its heat transfer capabilities. Recovery effectiveness (sensible only) for the pure-plate exchanger is in the range of 50 to 80%.

Having no secondary thermal transfer fluids, the effectiveness of a plate exchanger is essentially independent of operating temperature.

CONCERN ABOUT INDOOR AIR QUALITY IS BECOMING NOW WHAT ENERGY HAS BEEN FOR THE 70'S AND EARLY 80'S -- THE TECHNOLOGY TO WATCH.



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