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HUMIDITY CONTROLLED VENTILATION

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FUNDAMENTALS

Ventilation provides fresh air and exhaust of indoor air pollutants to reduce risk to the health of the occupants and damage to the building by condensation, mold, and mildew.

Humidity controlled ventilation (HCV) systems continuously vary airflows according to the humidity level of each room, which varies according to a number of different factors, such as occupancy, activities, room and ambient temperatures, etc.

At any given temperature, air can contain only a certain quantity of water vapor, and is then said to be saturated. Condensation occurs on cold surfaces, such as window panes, exterior walls, when the air in contact with these cold surfaces is reduced to the dew point, or is saturated.

Relative humidity (RH), expressed as a percentage, is the ratio of the actual water quantity contained in the air and the maximum quantity it can contain at saturation. The RH of the air in each room depends on the room temperature as well as the actual water vapor contained in the air.

The factors determining the RH of each room are the following:
(1) the number of people in the home (a man at rest emits about 40 grams of water vapor per hour),
(2) the occupancy level of the room (a vacant room will have a lower humidity level than when occupied),
(3) the utilization of each room, and activities going on (laundry, cooking, bathing, dishwashing, etc.),
(4) varying room temperatures (thermostat setback, zoned heating),
(5) the effect of air infiltration, outside air temperature and humidity.

ODORS AND POLLUTANTS

Humidity controlled ventilation systems rely on humidity as being the controlling variable determining the necessary ventilation rate. It is not the intent of this paper to justify the use of humidity level as a totally adequate parameter in setting the ventilation rate, but it can be observed that many of the pollutants of concern increase with increasing humidity level. In particular, carbon dioxide, and cooking emissions are accompanied by an increased humidity level. Even the rate of formaldehyde release from building products has been shown to be related to increasing level of humidity. Chemicals stored indoors represent another matter. (Let us hasten to add, that in the case of radon, the HCV system of ventilation being described here, will not be the most desirable mitigation technique, and may in fact increase the rate of radon entry into the home, since it will result in negative pressure indoors.) In the cases of odors from the kitchen and the half-bath, the odor is easy to detect and is easily resolved by the occupant as the need arises by a manual override.

In comparing HCV with accepted ventilation practices, one notes that in modern energy efficient dwellings, equipped with air and vapor retarders and heat recovery ventilators, a principal means of controlling the ventilation rate is the use of a dehumidistat.

DESIGN OF A VENTILATION SYSTEM WITH HCV

The first principle of an efficient ventilation system concerns where the exhaust outlets are located and how fresh air is introduced into the building. Pollutants can be exhausted most effectively and at minimum energy cost if the outlets are located close to the source of pollution. Hence, the service rooms, (kitchen, laundry, bathrooms, etc.) are exhausted. Fresh air is introduced into the main rooms such as the living and dining areas, family rooms, and bedrooms, so it can mix thoroughly with house air. Thus, a flow of clean air "sweeps" through the home, and pollutants, odors, and humidity are exhausted with a minimum of fresh air and subsequent heat loss. HCV systems further modulate the airflow rates by adjusting airflows in each room according to the relative humidity in each room.

It is important to note that HCV systems are not compatible with forced air heating systems, because the proper operation of the system depends on the local differences of relative humidity to direct the fresh makeup air into those rooms that are occupied. When used with hydronic, baseboard electric, or radiant heating, sufficient fresh air is introduced into individual rooms according to their level of occupancy, exceeding the ASHRAE minimum levels on a per room basis. However, if used with forced air heating, the humidity levels may be so low on average, that the fresh air supplied to the occupied room may be below the ASHRAE minimum.

The exhaust outlets, connected via ductwork to a central fan, are placed in the service rooms. The outlets in the kitchen, full bathroom, and laundry room respond to the individual room humidity by allowing a greater airflow at higher humidity levels, decreasing to a minimum airflow under dry conditions. Presently, two ranges are commercially available for the bathroom and laundry: 5 to 30 cubic meters per hour (3 to 20 CFM) and 12 to 50 cubic meters per hour (8 to 30 CFM). Each outlet has two humidity working ranges that can be chosen by the occupant: 25 to 60% RH and 40 to 70% RH. For the half-bath, since it is not a primary source of humidity, a closeable outlet with a timer is provided for the occupant for odor control. Similarly, the kitchen outlet is equipped with a manually operated bypass permitting a higher exhaust rate for cooking periods; otherwise, the kitchen outlet is identical to the outlets in the full bathrooms.

Fresh air replacing the exhausted air is introduced through humidity regulated air inlets installed high on the exterior walls in the main living areas and bedrooms. They serve to direct the incoming air to those rooms with higher levels of humidity, and restrict fresh air delivery to unoccupied drier rooms. The air inlets provide a variable free opening of 5 to 30 sq. cm. (0.78 to 4.65 sq. in.), adjusting the opening by means of a humidity sensing element that sets the damper position. Two humidity ranges can be selected on the fixture: 25% to 60% RH, for colder climates, and 40% to 70% RH for milder climates. The humidity sensor is located in the fixture, but is located out of the incoming airstream, so that it senses the average room humidity level.

EXAMPLE

The following example is illustrative of the principle of HCV only. It does not represent a real case, since the real leakage areas of the home are not considered.

Let us consider a home occupied by four people. Two outdoor temperatures will be considered: 0 °C and 12 °C, and an outdoor relative humidity of 78%. The home is equipped with HCV. We will look at three situations of different occupancy levels and activity in the home. (See figures 1-3).

(1) The home is vacant during the day.
(2) The kitchen, bath, living and dining areas are occupied during the evening hours.
(3) The bedrooms are occupied during the night, with different temperatures in various rooms.

In the first case, at 0 °C outdoors, the HCV total airflow is about 18 cubic meters per hour (about 10 to 11 CFM) giving a heat loss of about 109 watts. In contrast a ventilation system conforming to the 1982 regulation, (described later in this paper, setting the minimum ventilation rate according to 15(n + 2), where n = number of principal rooms, bedrooms plus living and dining rooms), gives a continuous ventilation of 90 cubic meters per hour, for a heat loss of about 545 watts. It may be observed that the total airflow of 18 cu. m./hr. is lower than the ASHRAE 62-1981 requirement. However, this is for an unoccupied dwelling.

At the higher temperature of 12 °C, the HCV total airflow is 39 cubic meters per hour, and the heat loss is about 78 watts. The constant system by comparison at 90 cubic meters per hour is giving a heat loss of about 182 watts.

The first case shows the effects of outdoor temperature on the airflows of the HCV system, and demonstrates that the ventilation heating costs are almost independent of outdoor temperature, and in this example even shows a slight decrease in power with falling outdoor temperature. Below 0 °C, this trend reverses and there is a slight increase again with falling temperatures, but the dependence on temperature is much less than that of constant ventilation or natural ventilation. With natural ventilation, the air change rate increases with falling outdoor temperatures, and the energy consumption increases even faster. This fact is of strong interest to utility companies plagued by peak demand in cold weather.

The second case demonstrates the automatic operation of the inlets and outlets in each room, redistributing the fresh airflows to those rooms where required. Note that with occupancy the total rate has now increased to 44 cu. m./hr. with 0 °C outdoors, and to 68 cu.m./hr. at 12 °C outdoors, with most of the increased air being supplied to the living dining area.

The third case shows the influence of differing room temperatures on the ventilation rate. Lowered room temperatures raise the relative humidity, requiring a higher ventilation rate to reduce the RH to acceptable levels avoiding condensation. In addition, the supply rate to the living and dining area has reduced, as the inlet dampers readjust to the lower humidity in that area, while the bedroom areas have both increased airflows.

Both the second and third example show compliance with the 10 CFM per room ASHRAE 62 requirement, while the rooms are occupied, except for the warmer bedroom in example 3 (14 cu. m./hr or 8.3 CFM).

To operate to its best advantage, the HCV system design must take into account the tightness of the building envelope. A complete analysis of the performance of the system under varying occupancy levels, building leakage areas, varying wind speeds, and ambient conditions is far beyond the scope of this paper. However, a few examples can be given to illustrate the effect of leakage areas.

A natural question arises concerning how much negative pressure can be induced with the system. Consider the following example as an extreme case. A single family dwelling with two bedrooms and a living-dining area, a kitchen and one bathroom. Suppose that the bedrooms and living-dining areas are unoccupied and dry; i.e., the air inlets are completely closed to their minimum opening of 5 sq. cm. each. Thus we have a total of 15 sq. cm. free opening, assuming zero natural leakage area. Further consider that the kitchen and bathroom are humid, so that the exhaust outlets are open allowing a high exhaust rate. The actual exhaust rate is determined by the duct pressure behind the outlet, and the free opening which is adjusted by the room humidity. The maximum free opening in the kitchen fixture is 16 sq. cm. and in the bathroom, 9 sq. cm., for a total exhaust opening of 25 sq. cm. The duct pressure is 10 mm w.g. (100 Pa). With these conditions, we can solve for the house static pressure and the exhaust and supply air flows. Using the relation

$$Q = k\,A\sqrt{\Delta P}$$

and letting
- Q = airflow (cubic meters/hour)
- k = coefficient = 1 for these openings
- A = free area of opening (sq. cm.)
- ΔP = pressure difference across opening (mm w.g.)
- Qe = exhaust airflow (cubic meters/hour)
- Qs = supply airflow (cubic meters/hour)
- π = indoor air pressure (mm w.g.)
- As = supply area (inlets + leakage area, sq. cm.)
- Ae = exhaust area (outlets, sq. cm.)

we obtain

$$Qs = A\sqrt{0-\pi} = Qe = A\sqrt{\pi - 10}$$

$$= 15\sqrt{0-\pi} = 25\sqrt{\pi - 10}$$

from which π = 7.35 mm w.g. (73.5 Pa or 0.28 in. w.g.)
and $Qs = Qe$ = 41 cu. m./hr. (24 CFM).

This is quite a negative pressure on the home. If we now consider a more realistic situation, in which we have a leakage area of 50 sq. cm., we get quite a lower negative pressure.

$$Qs = (50+15)\sqrt{0-\pi} = Qe = 25\sqrt{\pi - 10}$$

from which π = 1.29 mm w.g. (12.9 Pa or .04 in w.g.)
$Qs = Qe$ = 73.8 cu. m./hr. (44 CFM).

We can go further and show how these airflows are distributed:

Supply through leakage areas:	(50/65) x 73.8 = 56.8 cu.m./hr.
Supply through inlets:	(15/65) x 73.8 = 17.0 cu.m./hr.
Exhaust through kitchen outlet:	(16/25) x 73.8 = 47.2 cu.m./hr.
Exhaust through bathroom outlet:	(9/25) x 73.8 = 26.6 cu.m./hr.

ADVANTAGES OF HCV

Avoiding condensation. By automatically adjusting the ventilation rate according to the humidity level of each room, risk of condensation on cold surfaces is reduced. Of course, condensation is a function of the surface temperature and the wet bulb temperature of the air in the room. In cases of lowered room temperatures (zoned heating or thermostat setback), the HCV system automatically responds to the increased relative humidity by increasing the ventilation rate in that particular room, thus lowering the wet bulb temperature of the air, resulting in lowered condensation risk. Generally, for each 1 °C lowering of room temperature, an increased ventilation rate of 2 to 3 cubic meters/hour is required to avoid condensation on cold surfaces.

Energy saving. Because ventilation is provided only in rooms where it is required and only when it is required, the total air change is reduced to the absolute minimum by guaranteeing better air distribution. To better understand how much energy can be saved it is necessary to give some background information.

In France where this system has been given ministerial authorization from the ministries of social affairs, health, and housing, the building codes utilize the coefficient G to describe the heat loss characteristics of dwellings. The coefficient G of a dwelling is equal to its heat losses for one degree difference between inside and outside temperature divided by its habitable volume, and includes the heat losses by conduction and air change. (G= watts/cubic meter-°C). From 1969 to 1982 a series of code changes resulted in lowering the G coefficient in response to higher energy costs. In 1969, the air change rate was 1 ACH. In the 70's this was reduced to 0.5 ACH. In 1982 a new ventilation procedure was adopted, which with its amendments, resulted in adjusting the ventilation rate according to "n", the number of principal rooms, bedrooms plus living-dining. The 1982 regulation was 15(n+2), in cubic meters per hour. The allowable coefficient G ranged from 0.85 to 1.20, depending on the climatic zone, volume of the building, and the method of heating. Compared to the 1982 regulation, HCV permits a mean reduction of 10% of the total heating costs. Compared to the 1969 regulation, the G coefficient is reduced by 20% on the average. Remember, the G coefficient includes both conductive and air change heat losses.

The energy reduction aspect is presented here in terms of the G coefficient because of the statistical nature of the response of HCV systems as they are incorporated in social housing projects. To make this clear, consider that if an HCV system were installed in a small home with a high level of occupancy and a lifestyle that resulted in continuous high levels of moisture generation, all the exhaust outlets would be operating at their maximum exhaust rate, similar to a constant exhaust system. In such a case, there would be no energy reduction as compared to the constant exhaust system represented by the 1982 regulation. On the other hand, one can consider the case of an under-occupied dwelling, in which considerable savings may be achieved by the lowered exhaust rate during periods of low humidity. Thus, there is a certain range in which one must take a statistical average of moisture generation and occupancy levels, relate that to the airflows, and then calculate the resulting energy impact. When this procedure is done, the numbers quoted in the previous paragraph result, thus explaining why the various ministries were involved in the approval process for this departure from the established 1982 standard.

Reducing energy peaks during the winter. The colder the outside air, the lower its absolute humidity. When introduced into the home, this drier air provides a greater dehumidification effect. So, the colder the outdoor temperature, the lower the airflow required to maintain a comfortable humidity level. This overall reduction in airflow at colder temperatures results in lower ventilation heat loss as compared with natural or conventional mechanical ventilation.

Simple to install and operate. The system requires only a single speed fan, exhaust ducting, and the through-the-wall inlets. Because the different adjustments for each room are done automatically, the system requires no human intervention. No humidistat controls or other electrical controls are required. The only wiring necessary is the hard wiring of the single speed fan. All the flow controls operate passively.

Reduces the effects of infiltration/exfiltration. The home is kept under slight negative pressure. This results in reducing the effects of cross-ventilation due to wind pressure. It also reduces the exfiltration into wall cavities, thus diminishing moisture damage in wall cavities in cold climates.

INSTALLATION REQUIREMENTS

Exhaust outlets. All exhaust outlets are designed to fit 5 inch diameter ducting or sleeves. The humidity regulated outlets operate between 70 to 120 Pa (0.3 to 0.5 in. w.g.). The timed outlets in the half-baths operate between 50 to 150 Pa (0.2 to 0.6 in. w.g.) . Both types must be installed near the ceiling of all service rooms (kitchen, baths, etc.).

Air inlets. All air inlets must be installed in main rooms (bedrooms, living, and dining rooms, etc.) They may be installed in window frames, but better results are obtained when installed high on the walls using adjustable through-the-wall sleeves. An exciting possibility yet to be investigated for the northern climates is to integrate the inlets into the window assembly, creating a "dynamic" window, in which escaping heat through the window is captured by the incoming fresh air. Some preliminary work has been done in France and Sweden, as well as in Canada, similar to the dynamic wall concept reported on in this conference, by J. Timusk.

Ducting. NOTE: The following applies only to multi-family dwellings. Duct design must take into consideration the maximum airflows from each outlet, so that at least 60 Pa (0.4 in. w.g.) is available at the farthest outlet from the fan.

Fan. For best results from the exhaust outlets, the fan must have a flat fan curve, delivering at least 130 Pa (0.5 in. w.g.). The total airflow delivered by the fan is the sum of the kitchen and bathroom exhaust outlets plus half the airflow from the restroom (half-bath).

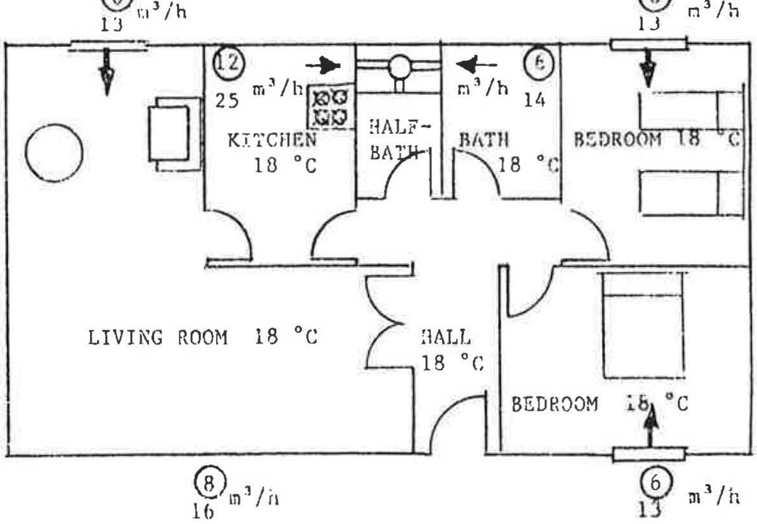
SUMMARY AND CONCLUSION

This paper has attempted to describe the most recent approach to central ventilation as is being practiced in France. The increased demand for lowered energy consumption over the last decade has resulted in reductions in allowable infiltration and ventilation levels. Various strategies have been employed, including simple exhaust systems, with passive self-regulating slot ventilators supplying the fresh air, as well as fully-ducted double flow heat recovery ventilators. In the last two years, the use of heat recovery ventilators in government-financed housing projects (which at one time accounted for about 15% of the ventilation strategies used) has largely declined and been superceded by the humidity-controlled ventilation system described in this paper. The major reason is that similar energy benefits are achieved using HCV, with about a 30% lower capital investment than with the air-to-air heat exchanger approach. Simple exhaust with self-regulating inlets, however, is still the most widely used method, with about 70% of the current market.

FIGURE 1.

VACANT DWELLING

OUTSIDE RELATIVE HUMIDITY 78%
OUTSIDE TEMPERATURE (0) °C
OUTSIDE TEMPERATURE 12 °C



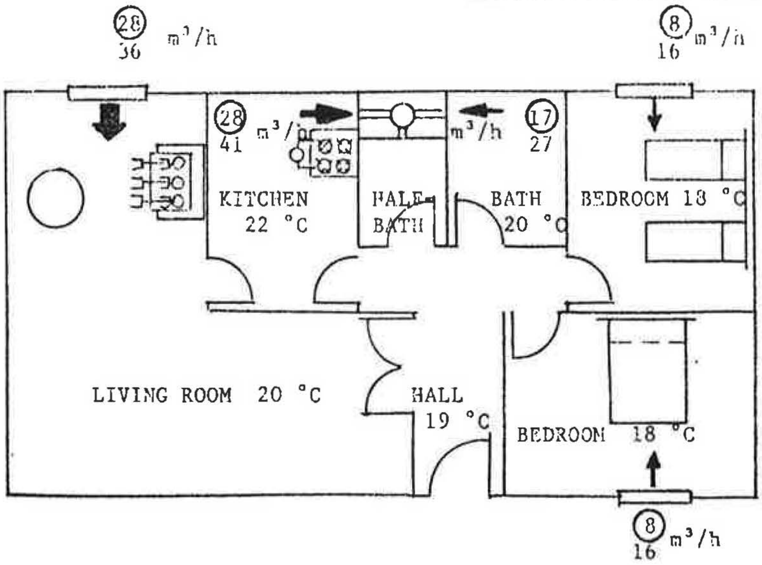


FIGURE 2.

EVENING OCCUPANCY

OUTSIDE RELATIVE HUMIDITY 78%
OUTSIDE TEMPERATURE (0) °C
OUTSIDE TEMPERATURE 12 °C

FIGURE 3.

NIGHT-TIME OCCUPANCY

OUTSIDE RELATIVE HUMIDITY 78%
OUTSIDE TEMPERATURE (0) °C
OUTSIDE TEMPERATURE 12 °C