EVALUATION OF THE PERFORMANCE OF ATTIC TURBINE VENTILATORS

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ABSTRACT

Attic turbine ventilators are increasingly used in residential applications to remove heated air from attic spaces during summer periods and, in turn, to reduce the energy transfer between attics and living spaces. Concerns have been expressed as to whether increasing attic ventilation rates may produce problems of interior condensation at wall-ceiling intersections during periods of low ambient temperature. In many instances, purchasers tend to expect dramatic improvements in the comfort level of living spaces when an attic turbine ventilator has been installed.

Field measurements of attic ventilation rates made in a house with and without a turbine ventilator indicated that the enhancement provided by the ventilator was a function of wind direction, with the greatest benefit in the direction with the most upwind shelter. Ventilation enhancement ranged between 5% and 50%. Averaged over all wind directions and seasons, the turbine ventilator increased ventilation rates by approximately 15% from 3.3 to 6.1 air changes per hour (ach).

Operation of an attic turbine ventilator was found to reduce attic air temperatures in the test house by a small amount, less than 1°F. Given the insulation levels in the ceiling of the test house, a temperature change of this magnitude is unlikely to influence occupant comfort.

INTRODUCTION

This study was undertaken in 1989 to determine the effect on ventilation rate of the installation of a turbine-type attic ventilator in a residential application. Turbine ventilators are devices composed of two parts—a base assembly that is fixed to the roof and centered over a hole through to the attic and a rotating element constructed in a manner similar to a centrifugal fan. The rotating element or turbine head spins under the influence of air moving over the roof surface and, while spinning, allows the egress of hot air from the attic space. Removal of warm air from the attic space should result in greater occupant comfort during the summer months by reducing heat transfer to the living space.

The study was prompted by a relatively large number of inquiries concerning the effectiveness of the ventilators in the removal of heated or moisture-laden air from the attic space. In addition, some concerns regarding condensation problems within the living area of homes were expressed. Evidently under certain conditions, the volume of cold air drawn through soffit vents and exhausted through the ventilator was sufficient to cause cooling of the interior drywall surface at the intersection of the wall and ceiling. A sufficient drop in surface temperature could result in condensation of water vapor from the interior air, resulting in moisture damage or, in extreme cases, the growth of mold and mildew. Although concern was expressed, no documented cases have been seen in the region.

PREDICTED ATTIC VENTILATION RATES

The prediction of attic ventilation rates with or without an attic ventilator installed is a complicated problem since very little is known about the conditions in or near the attic space. Flow paths, flow path resistance, and pressures inside and outside the attic are all unknowns. In addition, the structure may be sheltered by surrounding buildings or terrain on one or more sides, leading to further complications in the flow around the building and in the derivation of an accurate model.

Simplified Attic Model

One may, however, look at a simplified model of attic ventilation and in so doing obtain a better understanding of the potential a turbine ventilator may have for increasing attic ventilation. Figure 1 shows a generic attic in a house with a gable roof and vented soffits. Assuming, for simplicity, that the wind is from a direction perpendicular to the line of the roof peak, one can imagine a general flow path through the attic. Flow entering the upwind soffit and exiting through the downwind soffit would be regulated by the pressure distribution surrounding the attic and the flow path resistance. The physical system may be described by an electrical analogy, also shown Figure 1, in which voltage drop would represent the upwind-downwind pressure differential, resistance would represent the characteristic of the soffit to impede flow, and current would represent airflow. The electrical analogy for the attic with no ventilator would...
Figure 1  Schematic of a generic attic showing assumed flow paths and equivalent electric circuits.

simply be two resistances in series. The analysis is slightly more complicated since flow through sharp-edged holes, such as the perforations in soffit material, is not directly proportional to the pressure differential across the hole but to the square root, as indicated in Equation 1:

\[ Q = C\sqrt{\Delta P}. \]

When the ventilator is present, the electrical analogy becomes more complicated, as there are two flow resistances in parallel—the ventilator and the downwind soffit—and these two are in series with the resistance due to the upwind soffit. The electrical analogy for this configuration is also shown in Figure 1. Since one soffit and the ventilator are in parallel, an equivalent resistance can be calculated. The electrical analogy may be carried further if Equation 1 is rearranged in terms of head loss, as shown in Equation 2:

\[ \Delta P = \left( \frac{Q}{C} \right)^2. \]

Equation 2 represents the pressure or head loss across any flow path resistance that behaves like a sharp-edged hole.

Writing Equation 2 in a form similar to Ohm's law and setting \( 1/C^2 \) equal to \( K \) results in Equation 3:

\[ \Delta P = KQ^2. \]

Thus, when the flow is in the upwind soffit and out the downwind soffit, the electrical analogy consists of two resistances in series, with the total flow governed by the overall pressure differential and the sum of the two resistances. The system may be described in terms of head loss, \( \Delta P \), across each flow resistance. Equations 4 and 5 describe the head loss across the soffit and attic ventilator, respectively:

\[ H_{\text{soffit}} = K_{s}Q_{s}^2, \]

\[ H_{\text{vent}} = K_{v}Q_{v}^2. \]

Continuity requires that the flow into the attic be equal to the flow out of the attic, as indicated in Equation 6:

\[ Q_{\text{total}} = Q_{\text{soffit}} + Q_{\text{vent}}. \]

Since one soffit and the ventilator are in parallel, an equivalent resistance must be calculated before the overall circuit may be solved.

Writing Equation 6 in terms of head loss and resistance rather than flow, one gets

\[ \left[ \frac{1}{K_{s}} \right]^{1/2} = \left[ \frac{1}{K_{s}} \right]^{1/2} + \left[ \frac{1}{K_{v}} \right]^{1/2}. \]

In order to simplify the model, it is assumed that the ventilator and the downwind soffit each see the same pressure differential so that \( H_{s}, H_{v}, \) and \( H \) are the same. Examination of the work of Liddament (1986) and Wiren (1984) shows that the assumption of equal pressure differentials will be in error by less than 20% for the combination of house geometry and wind direction used. An error in pressure differential of 20% would result in an error in flow of approximately 10%. Equation 7 then simplifies to

\[ \left[ \frac{1}{K} \right]^{1/2} = \left[ \frac{1}{K_{s}} \right]^{1/2} + \left[ \frac{1}{K_{v}} \right]^{1/2}. \]

and can be easily rearranged to represent a single resistance equivalent to the original two parallel resistances, as shown in Equation 9:

\[ K = \left[ \frac{K_{s}^{1/2}K_{v}^{1/2}}{K_{s}^{1/2} + K_{v}^{1/2}} \right]^2. \]

The overall path resistance is then the sum of the soffit resistance and the equivalent of the soffit/ventilator parallel path. If it is assumed that the resistance of the soffit is not dependent on whether the flow is into or out of the attic, the overall head loss is given by Equation 10:
or, since the primary interest is the flow rate through the attic space, Equation 10 may be rewritten to solve for flow as a function of head loss, as indicated by Equation 11:

$$Q = \left( \frac{H}{K_s + \left( \frac{K_s^{1/2} K_v^{1/2}}{K_v^{1/2} + K_s^{1/2}} \right)^2} \right)^{1/2}.$$  \hspace{1cm} (11)

In order to predict the net flow through the attic space, the relative resistance of each flow path and the pressure distribution around the attic must be determined. Since the primary interest is gauging the effects of the attic ventilator, some assumptions concerning the flow path resistance may be made and the net change in exchange rate with the ventilator calculated. The turbine ventilator installed in the test house had a nominal 12 in. (305 mm) diameter base, giving an opening area of approximately 113 in.$^2$ (0.073 m$^2$). The soffit installed on each side of the test house was 28 ft$^2$ (2.6 m$^2$) in area, with 360 perforations per square foot. The perforations were produced by putting the soffit through a forming process that does not completely remove material but produces a series of louver-like recesses. Each recess had an open area of approximately .315 in.$\times$.020 in. (8 mm by 0.5 mm), producing a net open area of approximately 1.5%. The total open area in the soffit on one side of the house was 62.5 in.$^2$ (40,300 mm$^2$), or 55% of the area of the turbine ventilator base. Assuming that the soffit and turbine ventilator act like sharp-edged holes, the relative flow resistance can be estimated by considering the free area. Given that the flow resistance is proportional to $1/\text{area}^2$, the soffit resistance may be estimated as four times the turbine resistance.

When the ventilator is not present, the flow through the attic becomes approximately

$$Q_{\text{no vent}} = \left[ \frac{H}{2K_s} \right]^{1/2},$$  \hspace{1cm} (12)

while inclusion of the ventilator leads to

$$Q_{\text{vent}} = \left[ \frac{K_s}{K_s + \left( 1 + \frac{1}{9} \right)^{1/2}} \right]^{1/2}.$$  \hspace{1cm} (13)

The ratio of Equation 13 to Equation 12 shows the estimated increase in ventilation rate expected through the use of a turbine ventilator of the type described:

$$\frac{Q_{\text{vent}}}{Q_{\text{no vent}}} = \left( \frac{K_s}{2K_s} \right)^{1/2}.$$  \hspace{1cm} (14)

Note that although the open area in the attic through which ventilation air can enter or leave has been approximately doubled, the model predicts an increase in exchange rate of 34%. Figure 2 indicates the increase in attic ventilation rate expected as a function of the increase in attic exit area. As exit area is added to the attic, the flow through the attic increases as shown in the figure. Since the flow is limited, predominantly by the resistance of the inlet soffit, adding more exit area has less of an effect on total flow. Eventually, the addition of more exit area will have virtually no effect on the ventilation rate, as the flow will be governed entirely by the inlet resistance. At that point, the only way to produce increased flow is to reduce the resistance of the attic inlet.

The very limited mathematical analysis undertaken assumed that the pressure distribution was such that flow entered the upwind soffit and exited the downwind soffit and ventilator. It should be noted that the pressure distribution around the upper portion of a building and its roof is difficult to estimate, as it is a function of wind speed, direction, and local sheltering and may never be as assumed. It should also be noted that the positioning of the head of the ventilator (above the peak of the roof) may remove a great deal of direction dependence and as such enhance ventilation in conditions other than those assumed. Based on the above analysis, it should not be assumed that the ventilators are ineffective. What should be realized is that a turbine ventilator should not be expected to greatly enhance ventilation rates. Since the increase in ventilation rate should be moderate (and dependent on initial venting characteristics), it appears in general that the installation of a turbine ventilator would not cause any greater problems of interior condensation than would additional venting in the soffit.
VENTILATOR INSTALLATION IN A TEST HOUSE

In the foregoing analysis, an assumed pressure distribution and flow pattern was used to allow a simple description of a relatively complicated physical system. Neglected in the analysis was any method of dealing with the ventilator as a wind-driven centrifugal fan, which could conceivably produce low pressure in the attic space and draw air through the attic at a rate much higher than natural ventilation. In most circumstances, the ventilator is to be mounted on a sloped roof, near the peak. As a result, pressures inside the attic and outside near the rotating element are quite different those used in formulating the simple model. In addition, it would be expected that both the ventilator and the building would see wind speeds influenced by the surrounding terrain and adjacent buildings.

A ventilator was obtained, a flowmeter installed, and the calibrated assembly was installed on the roof of a test house. The mounting location was chosen near the peak to ensure unobstructed airflow from as many directions as possible. A cup-type anemometer was mounted on the roof near the ventilator to measure local air speed. The rotating elements of the ventilator and the anemometer were at the same height above the roof. Figure 3 shows the installation on the roof of the test house and the ventilator location relative to the peak of the roof.

EXPERIMENTAL RESULTS

Flow rate through the ventilator, ventilator height and 10-m wind speed, ambient temperature, and temperatures at various points within the attic were monitored using a computer-controlled data acquisition system. Temperature measurements were made using type-T (copper-constantan) thermocouples. Using the data acquisition system, temperatures could be resolved to 0.05°F (0.03°C), while measurement accuracy (including gain, A/D conversion, and reference temperature errors) was ±0.9°F (±0.5°C). The actual attic ventilation rate was measured continuously using a constant-concentration tracer gas system. The tracer gas system consists of an infrared gas analyzer, a computer-controlled data acquisition system, a tracer injector, and a sampling pump. The tracer gas system used has a resolution of 0.1 air changes per hour (ach). Discrete quantities of a tracer gas, R₂₂, were injected into the attic space at approximately four-minute intervals and mixed using fans in order to maintain a constant five parts per million (ppm). Multi-point sampling from the attic allowed determination of the average gas concentration over the interval. Knowing the concentration, C, and the quantity, V, of tracer added over any time interval allows the calculation of the ventilation rate,

\[ Q = CV, \]

where \( Q \) has the units of volume/time interval. Division of \( Q \) by attic volume produces air changes per hour.

In order to determine the effect of ventilator operation, attic exchange rates were measured with two different venting configurations: over two-week periods with the ventilator free to turn and two-week periods with the whole assembly blocked with a plastic cover. The two-week back-to-back testing was chosen to help eliminate variation due to environmental factors.

Attic Ventilation Rates

Attic ventilation rates in air changes per hour (ach) as determined with the tracer gas system are plotted against wind speed in Figure 4. The data gathered over the period March 1989 to December 1989 show periods when the ventilator was both blocked and unblocked. Examination of the figure indicates that, in general, the ventilator appears to provide a small increase in exchange rate. Given the amount of scatter in the data, however, a quantitative assessment is difficult.

One method of assessing the ventilator effectiveness over long periods of time is to simply calculate average ventilation rates with and without the ventilator. In both cases, ventilation rates range from less than one-half air...
change per hour (ach) to more than 20 ach. Mean exchange rates were found to be 5.3 ach with the ventilator closed and 6.1 ach with it open. Frequency distributions were determined for wind speed over the same time periods to determine whether a difference in mean wind speed could account for the difference in ventilation rates. Mean wind speeds were found to be 7 mph (3.1 m/s) for both ventilator-open and ventilator-blocked periods so that differences in speed alone could not account for the result seen. Based on the average measured exchange rates over the test interval, the turbine ventilator appears to have increased attic ventilation rates by 15%.

The test house used in the study is situated, as shown in Figure 5, in an east-west row of seven similar test buildings. Because of its location within the row, it is sheltered from east or west winds by adjacent buildings and is almost unsheltered from north or south winds.

To determine the effects of wind direction on attic ventilation rate, the available data were separated into 12 bins, each corresponding to an angle range of 30 degrees. Figure 6a shows attic air exchange rates measured under the influence of north winds, while Figure 6b shows rates measured during periods of west winds. While significant scatter is evident (primarily due to variation in wind direction over the one-hour averaging interval), it is evident that attic ventilation rates are higher for north winds (unsheltered) than for west winds of the same speed (sheltered). Best fit lines, determined through regression analysis, are shown on each figure for data collected with the ventilator operating and blocked. Comparison of the two figures shows that, in general, the attic ventilation rates are higher at all wind speeds when the winds are from the north than when they are from the west. The result was seen both when the ventilator was operating and blocked. This result was expected, given that the upwind shelter is much greater from the east or west than from the north or south. Comparison of the slope of the best fit lines indicates that for north winds, the operation of the ventilator resulted in an increase in the ventilation rate of approximately 10% at all wind speeds. It is surmised that under the influence of north or south winds, the flow is controlled largely by the resistance of the soffit to airflow. Measurements of attic air temperature indicated that under the influence of north winds, air flowed into the attic through the north soffit vents and out through the south soffit vents and turbine ventilator. When winds are from the west, one would expect to see reduced exchange rates due to the shelter provided by adjacent buildings. The ventilator appears to be more effective when winds are from the west, providing increased ventilation between 25% and 50%. During periods of east or west winds, it is difficult to estimate generalized flow patterns through the attic. It is likely that the soffit vents still provide the bulk of the resistance to flow, but that generally the flow will be in through both north and south soffits and out through the ventilator.

As was mentioned previously, the available data were binned in 30° direction increments. The data in each bin
were used to calculate a linear relationship between ventilation rate and wind speed for periods when the ventilator was both open and closed. Figure 7 shows the slope of each best fit line plotted against the corresponding predominant wind direction. (Directions measured in degrees clockwise from north.) No data were collected for winds between 210 and 240 degrees. The variation in the slope between direction bins can be interpreted as being due to differences in the physical construction of the attic as well as the variation in wind sheltering from surrounding structures. The ratio of the slope of the best fit line with the turbine open to that with the turbine closed gives an indication of the degree of ventilation increase produced by the attic ventilator in each direction bin:

\[
\text{% enhancement} = \left( \frac{\text{slope of best fit line with ventilator open}}{\text{slope of best fit line with ventilator closed}} - 1 \right) \times 100.
\]

Figure 8 shows the percentage change in attic ventilation rate over a wind angle range of 0 to 360 degrees with

0 and 360 both indicating north. Note that the maximum changes occur for east and west wind directions—the directions with the greatest amount of upwind shelter. This is an expected result, as the rotating element of the ventilator is above the roof peak and, as such, would see more uniform wind speeds from all directions than the soffit vents. The smallest amount of enhancement occurs, as it should, when the wind is blowing from directions that produce the greatest exchange rates. In those situations, the upwind and downwind soffits see the greatest difference in pressure so the cross-ventilation is already great and the ventilator contributes a lower percentage of the total flow.

Attic Air Temperatures

The primary reason for the purchase and installation of a turbine ventilator by a consumer has been cited as being the removal of warm air from the attic space during the summer months. Adequate venting of an attic space has two benefits: it can make the living space more comfortable and it can reduce the amount of energy used in air conditioning. 

Attic air temperatures were measured throughout the duration of the study—during periods when the ventilator was open and when it was blocked. Evaluation of the results is, however, quite difficult as attic temperature is a function of not only ventilation rate but also ambient temperature and the amount of solar radiation falling on the roof surface. In addition, the magnitude of the reduction of energy transfer to the living space is dependent not only on the air temperature in the attic space and the insulation level but also on what fraction of the total heat transfer occurs through radiation from the underside of the roof sheathing to the top surface of the insulation. If the radiation component is a large fraction of the total, the lowering of the attic air temperature through ventilation will not reduce the heat transferred to the living space by as much as one might imagine.

Attic temperature data for the spring and summer months were sorted into two groups—with and without the ventilator operating. The groups of data were binned in 1.8°F (1°C) increments of attic air temperature minus ambient air temperature and the resulting frequency distributions evaluated. With the ventilator operating, attic temperatures ranged from 7.2°F below ambient to 41.4°F (23°C) above during the April to September period. The mean temperature difference during the period was 10.1°F, indicating that on average the attic was 10.1°F (5.6°C) warmer than the ambient air. The data from the period when the ventilator was not operating showed a nearly identical distribution with a slightly higher maximum temperature difference of 45°F (25°C). The mean temperature difference during the ventilator-closed period was 10.8°F (6°C).

Comparison of the average temperature differences obtained with the ventilator operating and those with the ventilator blocked gives an indication of the effectiveness of the ventilator in reducing attic temperature and heat.
transferred to the living space. The data show a change in the attic ambient temperature difference of 0.75°F (0.4°C) over the summer period. Whether this change can be attributed to the attic ventilator or simply small differences in wind speed, wind direction, and solar radiation is not known. Given the insulation levels commonly found in residential attics, it is unlikely that the amount of energy transferred to the living space was reduced appreciably.

Attic Insulation Temperatures

In order to evaluate the potential for moisture condensation on the interior surface of the gypsum board during winter conditions, temperature measurements were made on the interior surface of the gypsum board and within the insulation on the north and south sides of the attic.

Figure 9a shows the locations of thermocouples in relation to the wall framing members and the wall/ceiling joint. Note that over the wall, there is only sufficient space to install R10 (RSI 2.11) insulation. Seven thermocouples placed within the insulation as shown give an indication of whether air is drawn through the insulation at a rate that would impair effectiveness. The interior surface temperature measurement allows estimation of the ambient conditions required to produce condensation on the interior surface of the gypsum board.

Measurements were taken in February and March 1989. In order to produce the most extreme conditions possible, sections of soffit in the immediate vicinity of the temperature probes were removed. This was done to maximize the volume of air drawn into the attic at the measurement locations. During the test period, the interior of the house was humidified on a continuous basis, producing relative humidities of approximately 40% at 70°F (21°C). For condensation to occur on the interior surfaces of the walls, the interior surface temperature would have to fall below the dew point, about 45°F (7°C). Figure 9b shows temperatures measured at various locations for a day in March with an ambient temperature of 16°F (-3°C), winds from the south at 12 mph (5.5 m/s), and the ventilator operating. Under these conditions, the temperatures measured on an interior drywall surface near the intersection of the wall and ceiling were 61°F (16°C) on the north side and 52°F (11°C) on the south. It is evident from the measurements that ambient air entered the attic through the soffits and exited through the ventilator and the north soffits. The interior surface did not reach the dew point, but ambient conditions were relatively mild.

To assess the potential for condensation on the interior surface of the drywall, data from November and December 1989 were examined. While it cannot be said that the period studied covers a full range of typical winter conditions, ambient temperatures ranged from -20°F to 65°F (-29°C to +18°C). During the entire period, the ventilator was operated to provide the most severe conditions possible (highest flow rates) in the attic insulation.

Hourly average interior surface temperatures were measured at the locations indicated in Figure 10 on the north and south sides of the house. As previously noted, condensation should not occur until such time as the surface temperature drops below the dew point. Over the November-December period, the surface temperature dropped below 45°F (7°C) for 26 hours, or 2% of the interval. Surface temperatures lower than the dew point on the south side of the test house were even less frequent, at less than 1% of the interval. The lower frequency seen on the south side of the structure is probably due to the south wall of the house being warmed by solar radiation and transferring some of that energy to the air entering the south soffit.

Although the potential for condensation existed for a portion of the interval, there was no evidence that condensation had occurred. It was evident from surface temperature measurements that the effectiveness of the insulation in reducing heat transfer was impaired by air movement. This result should not be misconstrued as being a result of ventilator operation. As long as a path through the insulation into the attic exists, some fraction of the air entering the attic will pass through the insulation. Whether or not the ventilator accentuated this problem was not conclusively shown by the study.

Measured Rates of Heat Transfer

Interior surface temperature measurements showed limited potential for interior condensation due to airflow through the ceiling insulation. The flow of air through the insulation can be greatly impeded by the installation of impermeable barriers, such as the insulation stops used with loose-fill insulation to keep it out of the space above the soffits. Barriers to air movement through the insulation should have the effect of reducing rates of heat transfer while increasing interior surface temperature and further decreasing the potential for condensation. In order to evaluate the effectiveness of insulation stops, heat flow transducers were placed on the ceiling to measure the rates of heat transfer at various ventilation rates. Figure 10 shows the locations of the transducers relative to the wall-ceiling intersection.

Rates of heat transfer were measured for several weeks before and after cardboard inserts, similar to insulation stops, were installed. The inserts were placed so that an unobstructed path to the attic remained while flow through the insulation was stopped. The measured rates of heat transfer along with the room-attic temperature differential were used to calculate an effective thermal resistance on an hourly basis. Figure 11 shows the effective thermal resistance measured at two locations on the south side of the test house over one week in January 1990. The cardboard air stops were put in place at approximately hour 82. There was an immediate increase in the effective thermal resistance at both locations, with the largest increase shown at the location farthest from the wall. The large decreases
in resistance between hours 36 and 50 and hours 72 and 80 show the strong dependence on wind direction. During both periods, wind was from the south, resulting in flow in through the south soffits and out through the north soffits and ventilator. After the installation of the barriers, the dependence on wind direction and on wind speed was largely removed, indicating that the stops were effective in limiting airflow through the insulation.

**MEASURED AND PREDICTED PERFORMANCE**

The objective of the study was to evaluate the performance of attic turbine ventilators through a field study. Estimating the attic ventilation rate based on measured flow through a ventilator would lead to the conclusion that the ventilator would provide a great increase in ventilation rates. It is only when a measured attic exchange rate is
compared to flow through the ventilator and to exchange rate without the ventilator that the true effect of the ventilator becomes apparent. The greatest enhancement is provided when the wind is blowing from a sheltered direction. In this case, the measured results shown earlier indicate that increases in exchange rate can be as high as 50%. For most other directions, the increase in ventilation rate is much less and depends on the physical construction of the attic and initial venting provisions.

In order to properly assess the effect of the addition of a turbine or any other type of ventilator, the concept of optimal ventilation rate must be addressed. Prior to this study, there was very little information available on the ventilation characteristics of attics, nor was there any good estimate of the range of ventilation rates one might encounter in a residential attic. Measured attic ventilation rates (without a turbine ventilator) over the course of the study varied between 1 and 20 air changes per hour, with an average of more than 5 air changes per hour. Given this level of exchange rate in an attic that simply has soffit vents, the need for enhancement becomes questionable.

CONCLUSIONS

The ventilation rate of an attic is dependent on a number of parameters, such as the type of soffit, the free area of the soffit, wind speed, and local sheltering. There is a large degree of uncertainty associated with estimated rates as derived through laboratory experimentation.

Using the simple model derived for attic ventilation, an estimate of the change in ventilation rate due to the installation of a turbine ventilator was made. Given the assumptions that were used in deriving the model and recognizing that the potential for increased ventilation is a function of the initial ventilation rate, a prediction of 20% to 30% increase in ventilation is reasonable.

Attic ventilation rates were found to vary from less than 1 ach to more than 20 ach, with an average of 5.3 ach when only soffit vents were used and 6.1 ach when the turbine ventilator was used in addition to soffits. Enhancement provided by the turbine ventilator was found to be dependent on wind direction and ranged from less than 5% to more than 50%. Based on average measured exchange rates, the turbine ventilator provided an actual increase of 15% in attic ventilation rate over a one-year period.

It was found that flow into the attic through soffit vents was such that the effectiveness of insulation placed over the wall top plate was reduced, and that insulation effectiveness over the top plate could be largely restored by the use of insulation stops. The potential for interior condensation on the ceiling near the wall-ceiling intersection increased with the severity of ambient conditions, but it was not shown conclusively that the installation of a turbine ventilator would increase the risk appreciably.

Experimental work was undertaken using only one turbine attic ventilator on the roof of the test house. Multiple turbine attic ventilators, as are used in some installations, should provide a marginal enhancement over that afforded by a single ventilator. Again, unless one or more of the ventilators acted as inlets rather than outlets, the overall ventilation rate would be governed by the resistance of the inlet soffit material.

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