A Study of Indoor Air Quality in South Central Alaska

Executive Summary

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Foreword

This study was conducted by Wisdom & Associates, Inc in the winter of 2003-2004. It was made possible by a grant from the Cold Climate Housing Research Center. We would like to thank the staff at the Cold Climate Housing Research Center for their support in this study which helped 100 families on the Kenai Peninsula and has added information on the subject of indoor air quality to the building industry in Alaska.

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Abstract

This study was funded by Alaska's Cold Climate Housing Research center, and conducted by Wisdom & Associates, Inc. The purpose of this study was to identify underlying root causes of poor indoor air quality problems on the Kenai Peninsula. One hundred homes were selected fro the study in the winter of 2003-2004. The 100 homes tested varied in age, size, occupancy, and energy efficiency. The indoor air contaminant levels were monitored for a minimum of 48 hours. Temperature, relative humidity, carbon monoxide, carbon dioxide, radon, and ultrafine particles were measured in each home. This study examines the results by contaminant type; radon, carbon monoxide, carbon dioxide, relative humidity, and ultrafine particles. Other topics covered were condensation, mold, sooting, pressure imbalances, ventilation, energy rating, garage type and heating system configuration. Results showed that most poor indoor air quality problems can be categorized under the umbrella of ventilation, which includes adequate supply, exhaust, and circulation; pressure imbalances and air pressure limitations, vapor barriers and combustion air. This study also found that many problems develop under the umbrella of the house is a system. The house must be examined and regarded as a system that works in relation to its components, which includes the occupants.

Key words: Indoor air quality, relative humidity, carbon monoxide, carbon dioxide, radon, ultrafine particles, condensation, mold, sooting, pressure imbalances, ventilation, energy efficient building, garages, heating systems, house as a system.

Chapter 2

Executive Summary

No single factor can be blamed for poor indoor air quality. Poor indoor air quality is a result of interactions between the occupants and systems within the home. The first root cause behind poor indoor air quality falls under the umbrella of ventilation. Proper ventilation includes adequate fresh air exchange for the occupants, awareness of pressure imbalances and air pressure limitations, well sealed vapor barriers and combustion air. A balance of all of these factors results in good indoor air quality. Focusing on any single area without looking at the big picture within the home may aggravate indoor air quality problems. The occupants of the home are a good indicator of whether or not there are indoor air quality problems present. There is a direct correlation between the quality of indoor air and occupant health.

Proper ventilation and adherence to the BEES ventilation standard is a key solution to reducing indoor air quality contaminants. Mechanical ventilation is much more effective than natural air leakage, and is strongly recommended with strict attention being paid to pressure imbalances. Proper ventilation is the key to; reducing indoor Radon levels, keeping Carbon Monoxide levels as low as possible in the home, reducing relative humidity in the home, preventing mold problems in the home, and is the best protection against elevated Carbon Dioxide levels within the home. Carbon Dioxide levels in the home are directly related to the number of occupants in the home. Carbon Dioxide is also a significant indicator of other indoor air quality issues in the home

The second broad umbrella we can categorize poor indoor air quality under is not treating and recognizing that the house is truly a system and that all of its components, including the occupants, must work in tandem to keep indoor air quality problems from developing. If one component is ignored within the home, it does not just affect the one area, it affects the whole house.

This study will demonstrate that it is important to treat the home and its components as a system to reduce the likelihood that the home will add to, or compound poor indoor air quality problems. This includes providing ventilation to the structure, adhering to pressure imbalance guidelines, following building codes and educating the home's occupants. When the home is recognized as a system, and diagnosed and treated as such, problems that develop can be used as a roadmap for adjusting the home's components to meet occupant needs. When a balance between the home's components and the occupants needs is reached, the likelihood of poor indoor air quality problems is reduced.

Radon Summary

Radon is a naturally occurring radioactive gas which is produced when uranium and radium break down in the earth's crust. Radon is the second leading cause of lung cancer in the U.S. behind smoking, causing a suspected 15,000 to 22,000 deaths per year. Radon is also classified as a Group A carcinogen. The most common entrance point for radon gas is through the soils that surround a home. Soil gases enter a home typically through the foundation and under floor area of a home.

The EPA estimates that 1 out of every 15 homes in the United States has elevated radon levels. In general, the average indoor radon level is estimated to be 1.3 pCi/L, and the average outdoor radon level is estimated to be 0.4 pCi/L. The EPA states that no level of radon is safe and that most homes today can be reduced to 2pCi/L or below. Anything at 4 pCi/L or above should be remediated. (EPA, 2002)

Therefore in our study of 100 homes we classified a home's average radon level into 3 categories. Low category homes had average radon levels between 0 and 2.0 pCi/L, medium radon category homes had average readings between 2.1 thru 3.9 pCi/L, and high category homes had average levels of 4.0 pCi/L and above. By EPA guidelines those homes in medium and high categories were recommended to take steps to reduce their radon levels.

The EPA feels that no level of radon is safe; however, with the technology available today, it is not economically feasible to reduce levels to below 2.0 without undue cost. Therefore it is recommended that if your home's radon levels are between 2.1 pCi/L and 3.9 pCi/L steps should be taken to reduce the radon in the home.

To gain a better idea of where the 100 homes fell into radon levels, 54% of the homes had average levels between 0 and 2 pCi/L, 25% had average readings between 2.1 and 3.9 pCi/L, and 21% of the homes had average indoor radon levels of 4.0 pCi/L and above. Roughly half of the homes are within levels the EPA feels cannot be improved upon at this time because of a lack of technological advances, and half of the homes fall within a category that should be remediated to reduce their radon levels. With roughly half of the homes exhibiting a need for radon remediation, we begin to look for a common cause in the elevated radon levels in these homes.

Two significant findings occurred in regard to Radon during the study. The first significant finding was that as the number of air changes per hour increased in homes, the level of Radon decreased. The most airtight homes in the study, those classified as having between 0 and 3.9 air changes per hour at -50 Pascals, had on average the highest levels of Radon at 3.63 pCi/L. As the air tightness of the homes decreased, so did the Radon levels. Homes in the 4 to 6.9 air changes per hour had Radon levels 11% lower at 2.96 pCi/L. Homes in the 7 to 9.9 air changes per hour had Radon levels 152% lower at 1.44 pCi/L. Homes with 10 air changes per hour had radon levels 252% lower at 0.95 pCi/l.

The second significant finding was that as the negative pressure imbalances in the home increased, so did the level of Radon. The average radon level is 20% higher in homes with medium pressure (negative 5.0 to 9.9 Pascals, house with reference to the outside) imbalances and 84% higher in homes with high pressure imbalances (negative 10.0 Pascals or greater, house with reference to the outside) when compared to homes with low pressure imbalances (negative 4.9 Pascals or less, house with reference to the outside). As the pressure imbalance of the house with reference to the outside increased, so did the average radon levels in the house. This would be due to the house starving for air and bringing it through random cracks in the house and crawlspace and/or foundation. This means the house is pulling soil gases into the house; including radon. As the house draws more air from the outside, it draws more soils gases into the house; therefore we see homes with a high pressure imbalance also have elevated radon levels.

There was not a significant relationship between the foundation type and the average level or Radon in the home. However the numbers did indicate that homes with a foundation system that can be ventilated, such as a crawlspace or pilings, had lower Radon levels than homes with a slab. The average radon levels are 127% lower in a home with a combination crawlspace and slab, 43% lower in a home with a crawlspace and 521% lower in a home on pilings when compared with the average radon levels in a home with a slab.

There was not a significant relationship between the presence or condition of the vapor barrier and the average level of Radon. It must be noted that only 5 homes in the study did not have a vapor barrier present and only 7 homes had a poor vapor barrier condition. These small numbers may not be representative what is actually occurring in homes.

There was not a significant relationship between whether homes met the BEES ventilation standard, how they met the BEES ventilation standard (Option I, Option II), and what type of ventilation was used to meet the BEES standard (natural air leakage, mechanical etc.) and the level of Radon. It is important to note that homes that did not meet the BEES ventilation standard had Radon levels 33% higher than homes that did.

In conclusion, this study indicates that the best line of defense against Radon is a properly installed vapor barrier in the crawlspace or under a slab, proper ventilation of the home to reduce Radon that enters the living space, and minimizing negative pressure imbalances within the home that draw Radon gas out of the ground and into the home.

Carbon Monoxide Summary

Carbon Monoxide is readily known throughout the community as the silent killer because each year we hear of deaths from carbon monoxide poisoning. Carbon monoxide is an odorless, tasteless, sightless gas that displaces oxygen in the body becoming life threatening to everyone at elevated levels. (EPA Website, 2004)

In the 100 homes in our study, none of them experienced elevated levels of carbon monoxide over 9 ppm for an 8 hour period, which is the EPA maximum suggested exposure for an 8 hour period. We did see elevated levels that were tied to events, but most background levels were below 5 ppm.

In general, of the 100 homes we tested the average carbon monoxide (hereinafter referred to as CO) was 2.10 ppm, the average high was 7.05 ppm and the average low reading was 0.62 ppm. For simplicity, we have broken CO levels down into a low, medium and high category to look at general trends in the data. A low CO level was classified between 0-1.9 ppm, a medium reading was classified as a 2.0-4.9 ppm, and a high level of radon was 5 ppm and above. Of the 100 homes, 52% averaged low levels of CO, 43% averaged medium levels, and 5% averaged high levels of CO. These CO categories relate to readings taken in the house.

Homes that use a fireplace frequently have 30% less Carbon Monoxide in the living space on average than homes that do not use a fireplace very often. The lower levels of Carbon Monoxide found in homes that use the fireplace frequently can be attributed to the additional ventilation the home receives from the fire place draft.

Homes with a fireplace present had on average 40% less Carbon Monoxide in the living space than did homes without a fireplace. This can be attributed to the fact that fireplaces ventilate the home through stack effect and draft, reducing the levels of Carbon Monoxide.

There is not a statistically significant link between the level of Carbon Monoxide and the type of range hood in the home. Homes with recirculating range hoods did not have significantly higher Carbon Monoxide levels than homes with range hoods vented to the outdoors. This can be attributed to the fact that very few occupants used the range hood when they cooked; making the type of range hood they had irrelevant.

Homes that used natural gas as the cooking fuel had 194% higher average CO readings in the living space than homes that used electricity. Homes that used propane as the cooking fuel had 187% higher average CO readings in the living space than homes that used electricity.

There was not a significant relationship between whether or not smokers were present in the home or where smoking took place in the home and the average CO level in the home. However, the average CO levels in homes without smokers are 11% lower than in homes with a smoker present, and homes with people who smoked outside had 25% lower CO levels than homes with people who smoked in the house.

There was not a significant relationship between the age of the cooking appliance and CO levels in the home.

There was not a significant relationship between the type of heating system (boiler, forced air or space heat), heating system fuel type, heating system age or heating system location and CO levels in the home. However, the average CO level in homes with a boiler was 16% higher than in homes with a space heater. The average CO level in homes with a forced air heating system was 38% higher than in homes with a space heating system. Also, the average level of CO in homes with oil heat was 23% lower than in homes with natural gas heat and homes with heating appliances located in the garage had 20% higher CO levels than homes with heating appliances located in the living space.

There was not a significant relationship between the hot water heater type, hot water heater fuel type, or hot water heater location and the average CO levels in the home. However, homes with a boiler mate hot water heater had 224% higher CO levels than did homes with a standard gas tank. This is because homes that use a boiler mate rely on the boiler to supply both the heating and domestic water. This increased load on the boiler means it will fire more often and produce more CO. Homes with on demand hot water systems had 90% lower CO levels than homes with a standard gas tank hot water heater. Homes with an electric hot water tank had 25% lower CO levels than did homes with a standard gas fired tank. Also, homes using electricity as the hot water fuel had 69% lower CO levels than homes using natural gas.

There was not a significant relationship between the weakest combustion category appliance present in the home, the presence of combustion air, whether or not an appliance back drafted under worst case scenario pressure imbalance testing, or the negative pressure imbalances present in the home and the average CO levels in the home. However, the largest percentage of homes within the high CO average category were those homes that had a 4 star energy rating or less, which are not considered unusually tight. Also, homes with medium pressure imbalances had CO levels 17% lower than homes with low pressure imbalances. Homes with high pressure imbalances had CO levels 5% lower than homes with low pressure imbalances.

There was not a significant relationship between whether or not a home met the BEES ventilation standard, under what option a home met the BEES ventilation standard, the type of ventilation present in the home, or whether of not the HRV was balanced and the average CO levels in the home. However, the average CO levels of homes that did not meet the BEES Ventilation Standard are 29% higher than in homes that did meet the BEES Ventilation Standard. This can be attributed to the fact that homes that meet the BEES standard are better ventilated than homes that do not meet the BEES standard, which makes it more likely those contaminants such as CO will buildup inside the home.

There was not a significant relationship between the leakiness of the structure measured in ACH and the average level of CO in the living area.

In conclusion, proper ventilation is the key to keeping Carbon Monoxide levels as low as possible in the home.

Carbon Dioxide Summary

Carbon Dioxide is a colorless, odorless, tasteless gas. Significant sources of Carbon Dioxide produced in the home are from people as a waste product when they breathe and also as part of the combustion process. Besides a home's occupants, sources of Carbon Dioxide include heating and cooking appliances as well as any other appliance or activity in the home that utilizes the combustion process.

The American Society of Refrigeration, Heating, and Air Conditioning Engineers, hereafter referred to as ASHRAE, has set the exposure limit for Carbon Dioxide in the

ASHRAE Standard 62-2001 at 1000 parts per million for continuous exposure. Carbon Dioxide concentration is also regarded as an indicator of overall indoor air quality. Symptoms of excessive Carbon Dioxide levels include stiffness, drowsiness, stuffiness and lack of energy. (ASHRAE, 2001) (Persily, 1996)

Of the 100 homes tested, 99 had valid Carbon Dioxide (hereafter referred to as CO2) readings. One house had a unit malfunction during testing. CO2 levels were classified in three categories; 0 ppm – 699 ppm was considered low, 700 – 999 was considered medium and 1000 ppm and above was considered high.

Overall, 24.2% of homes had low average levels of CO2, 32.3% had medium levels of CO2, and 43.4% had high levels of CO2.

There is a statistically significant relationship between the number of occupants in the home and the CO2 level. This correlation is logical because people are a key source of CO2 in the home, and more people means greater CO2.

There is a statistically significant relationship between homes with fireplaces and CO2 levels. The numbers seem to show that homes with draftier fireplaces have lower levels of CO2. In effect the leakiness of the fireplace helps ventilate the structure, which in turn lowers CO2 levels. There is also a statically significant relationship between how often fireplaces are used and the CO2 levels in the home. Fireplaces use a lot of fresh air to maintain draft and burn properly. Fresh air from the outside used in the combustion process lowers CO2 levels in the home.

There is a significant link between CO and CO2 levels. If ventilation is the key to removing contaminants from the home, it would make sense that these two contaminants would be linked together. These two contaminants also have a common source in the combustion process, and the most common open combustion process in the home is the cooking stove.

There is also a significant link between relative humidity in the home and CO2. Many of the same processes that produce CO and CO2 also produce humidity in the home (cooking, occupant respiration etc.). If the home does not have adequate ventilation, all three of these contaminants will likely buildup together.

There was not a significant relationship between the age of the house, the number of bedrooms, the heating fuel type, the heating appliance system type, the heating system location, the hot water fuel type, hot water appliance type, cooking stove age, cooking stove fuel type, stove range hood type, number of smokers in the home, smoking area in the home, ventilation system type, whether or not the home met the BEES standards, the method of ventilation, whether or not the HRV was balanced, if applicable, the operator knowledge of the HRV system, if applicable, the ventilation air type, negative pressure imbalances, the combustion category of the heating weakest appliance or whether or not the a heating appliance in the home back drafted under worst case scenario negative pressure imbalance testing and Carbon Dioxide levels in the home.

Carbon Dioxide levels in the home are directly related to the number of occupants in the home. Carbon Dioxide is also a significant indicator of other indoor air quality issues in the home. Proper and adequate ventilation is the best protection against elevated Carbon Dioxide levels in the home.

Relative Humidity Summary

Relative humidity is the amount of moisture in the air relative to the amount of moisture the air could hold if the air was saturated. Relative humidity is described as a percentage. While water vapor suspended in air is not harmful in itself, it may create an environment that promotes the growth of biological contaminants. These contaminants include things like mold, viruses, bacteria, and dust mites. A healthy indoor environment will maintain 35% to 45% relative humidity during the winter months. More than 45% relative humidity will allow biological contaminates to thrive and pollute the indoor air.

Condensation occurs when the relative humidity hits 100%. This happens in a home when the indoor air temperature cools to the point that it can no longer hold water vapor and liquid water forms. Excessive humidity combined with cold surfaces inside the home cause condensation which in turn promotes the growth of biological contaminants.

For simplicity reasons, we have again categorized relative humidity levels (hereinafter referred to as RH) into three categories of low, medium and high. Low RH levels are considered below 30%, medium levels are between 31-45%, and high levels are categorized as above 46%.

As the number of bedrooms in a home increases, the relative humidity decreases. This would be due to the volume of the home increasing so there is more air for the moisture to saturate. With reference to a one bedroom house the RH average in a home is 9% lower in homes with two bedrooms, 16% lower in a three bedroom, 28% lower in a four bedroom, 37% lower in a five bedroom and 28% lower in home with seven bedrooms.

There is a correlation between the number of bathrooms and the RH levels in the house. As the number of bathrooms in a home increases, the RH moves down in both percentage of homes that fall into high and medium RH categories, but also the average RH level of the home. We attribute this to larger homes with more of an air volume that can handle additional moisture in the air. The average RH level was 20% lower in homes with two bathrooms, 20% lower in homes with three bathrooms and 33% lower in homes with four bathrooms. Of the homes tested in this study, there was not a linear relationship between the number of occupants and the square footage of the home, i.e. larger homes did not necessarily have more occupants. For example, homes with a single occupant were an average of 1303.5 square feet, while homes with seven occupants were an average of 1159 sqaure feet.

The RH was 21% higher in homes with pilings, 14% higher in homes with a crawlspace, and 10% higher in homes with a slab and crawlspace combination than in homes with a slab only. Piling homes had the highest relative humidity levels in the living space because the piling homes studied were skirted without ventilation and did not have a vapor barrier over the ground. This allowed moist air to build up under the house and be drawn into the house through stack effect. Crawlspace homes faced a similar situation, even though a vapor barrier was usually present. Moist air built up in the crawlspaces because ventilation to the outside because of winterrime conditions. Moist air then migrated into the living space through stack effect. A proper vapor barrier and adequate ventilation is still the best line of defense against excessive moisture in the crawlspace.

As the condition of the crawlspace was drier, less moisture was found in the air of the living area. The average RH level was 27% higher in a home with a damp crawlspace than in a home with dry crawlspace. This shows that there is not only a connection between the crawlspace and the house, but that a damp crawlspace can be a tremendous source of moisture in the house.

We observed that as the vapor barrier was removed from the crawlspace, the RH averages in the house increased. This shows that a vapor barrier is important in keeping excess moisture out of the house, as a good vapor barrier will stop moisture at one of its sources. A proper vapor barrier and adequate ventilation is still the best line of defense against excessive moisture in the crawlspace.

There was a statistically significant relationship between the condition of the vapor barrier and the relative humidity levels in the crawlspace. As the vapor barrier became tighter, outside air infiltration was reduced which causes the crawlspace RH to rise. Moist air built up in the crawlspaces because ventilation to the outside was closed. All of the homes tested during the study had ventilation to the outside closed because it was wintertime when the study was conducted. Moist air then migrated into the living space through stack effect. A proper vapor barrier and adequate ventilation is still the best line of defense against excessive moisture in the crawlspace.

There was a statistically significant relationship between the garage type and the level of relative humidity in the home. Homes that had a detached garage or did not have a garage had higher relative humidity levels than homes with attached or tuck under garages. This is because in most homes the garage is the leakiest part of the house. Cool, dry air migrates from the outside to the garage and into the house, decreasing the relative humidity in the living space.

There was not a significant relationship between the age of the home, the frequency the car was parked in the garage, the type of heating system, the heating appliance combustion category, whether or not the home met BEES ventilation, the ACH rate at -50 Pascals, or the type of ventilation and the level of Relative humidity in the home.

As the volume of houses increase, the level of relative humidity in the home decreases. A proper vapor barrier in the home eliminates a large source of moisture in the indoor air. Proper and adequate ventilation is the best method of reducing humidity inside the home.

Condensation Findings

Condensation is one of the first indicators that the indoor air quality in the home may be poor. Moisture enters the air through normal household activities like showering, washing dishes, laundry and breathing. A family of four can produce up to 27 gallons of moisture in the air per week through normal household activities. When this moisture is allowed to build up in the home condensation may occur.

Condensation forms when air with a high relative humidity is cooled down. Since warm air can hold more moisture than cold air, when the air is cooled down it is not able to hold the moisture and the result is visible beads of moisture or condensation. In a house with high relative humidity, the area most likely to cool off first and allow condensation to form is on the window or on the inside of exterior walls. When this warm moist air hits the cool surface of the window or the inside of an exterior wall, the result is condensation forming.

Condensation cannot be measured in a truly objective way; however, every effort was made to maintain consistency in describing the amount of condensation.

Where applicable, condensation was described as present or not present. This included actual water on window surfaces or evidence of water staining.

Where applicable, condensation was considered light when 1/3 or less of the window pane had moisture on it, or staining was present on less than half of the window sills in the home. Condensation was considered heavy when covered more than 1/3 of the window surface, or the entire window sill showed water staining in the house. Rot or sheetrock damage was noted when condensation was or had recently been so heavy as to actually cause rot to form on the window sill or damage had occurred to the sheetrock.

Of the 100 homes sampled, 94 had some evidence of condensation present.
Out of the 100 homes sampled, 66 had light condensation, 26 had heavy condensation, and 2 had rot or sheetrock damage.

Initially, it might be assumed that the level of condensation would increase as the number of bathrooms increased because bathrooms are a moisture source. However, the numbers indicate that the opposite is true. The level of condensation decreases as number of bathrooms increase. This could be attributed to the fact that the amount of occupants in the home stays relatively the same, but houses increase in sized with the number of bathrooms. The larger houses have more volume that is available to absorb the humidity and more air leakage is present to lower humidity levels.

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Slab/basement foundations had the least amount of heavy condensation at 11.8%, crawlspaces had 35.8%, combination slab/crawlspaces had 40.0% and pilings had the greatest percentage of heavy condensation at 50.0%. Piling homes had the greatest percentage of heavy condensation in the living space because the piling homes studied were skirted without ventilation and did not have a vapor barrier over the ground. Homes in this study with a combination slab and crawlspace had the second greatest percentage of heavy condensation. This could be attributed to the fact that these homes were typically tri-level, meaning they were taller than the typical home studied and more vulnerable to stack effect. This increased stack effect may have drawn excess moisture from the crawlspace and resulted in heavy condensation.

66% of the homes with a damp crawlspace had heavy condensation vs. 33.9% of homes with dry crawlspaces. This suggests that the crawlspace is a source of moisture in the home.

Homes with a vapor barrier have more heavy condensation than homes without. When a vapor barrier was present, outside air infiltration was reduced which caused the crawlspace RH to rise. Moist air built up in the crawlspaces because ventilation to the outside was closed during the study because of closed house conditions. Moist air then migrated into the living space through stack effect. A proper vapor barrier and adequate ventilation is still the best line of defense against excessive moisture in the crawlspace.

Homes with a good vapor barrier have more heavy condensation than homes with a fair or poor vapor barrier. As the vapor barrier became tighter, outside air infiltration was reduced which causes the crawlspace RH to rise. It was also our observation that cold water pipes in the crawlspace caused condensation, which formed pools of water on the crawlspace floor. As liquid water built up in the crawlspace, it caused humidity levels to rise. Moist air built up in the crawlspaces because ventilation to the outside was closed. All of the homes tested during the study had ventilation to the outside closed because it was wintertime when the study was conducted. Moist air then migrated into the living space through stack effect. A proper vapor barrier and adequate ventilation is still the best line of defense against excessive moisture in the crawlspace.

Homes with heavy condensation had an average RH nearly 6% higher than homes with light condensation.

There was not a significant relationship between the number of bedrooms, the number of bathrooms, the number of occupants, foundation type, crawlspace condition, presence of a vapor barrier, condition of the vapor barrier, window type, window frame type, or the relative humidity in the home and whether or not condensation was present and at what level condensation was present on the windows of the home.

The condition of the crawlspace plays a role in whether or not condensation will be present n the windows.

Mold Summary
The mold observations in this study were visual only and no air sampling or any other type of mold testing was done. We began by asking the occupants if they knew of any place in the house where mold was growing. If the occupants suspected mold growth they would take us to that area and we would make our observations about whether it was mold, and if mold present, whether it was light, medium or heavy mold covering. If the home owner did not know of any places that mold was occurring we would check for signs of mold during the walk-through, and make note of our findings.

If mold was present in the house it was categorized into light, medium or heavy mold coverings. Light mold coverings were classified as a few individual specks of mold growing on window sills. Medium mold covering was classified as mold growing in the corners of the windows and along the frame. Heavy mold covering was noted when the window sill had substantial mold on the frame but also the track and the sill.

Mold growth on the walls was noted and categorized in much the same manner. Again, mold was broken down into light, medium and heavy categories. Light mold was classified as mold present in one or two corners, less than 1 square foot in total area. Medium mold was 1-5 square feet of coverage and heavy mold was greater than 5 square feet of coverage.

It appears that there is a trend that a balanced HRV unit will decrease the likelihood of mold and the severity of mold on the windows.

42.3% of homes without a ventilation system had mold present on the walls, only 4.5% of homes with a mechanical ventilation system had mold present on the walls.

Homes with no ventilation system were 300% more likely to have mold present on the window sill than not. Homes with HRVs were half as likely to have mold on the window sills as not.

Homes with a vapor barrier present were more likely to have mold growth on the walls. When a vapor barrier was present, outside air infiltration was reduced which caused the crawlspace RH to rise. It was also our observation that cold water pipes in the crawlspace caused condensation, which formed pools of water on the crawlspace floor. As liquid water built up in the crawlspace, it caused humidity levels to rise. Moist air built up in the crawlspaces because ventilation to the outside was closed during the study because the study was conducted in the wintertime. Moist air then migrated into the living space through stack effect. A proper vapor barrier and adequate ventilation is still the best line of defense against excessive moisture in the crawlspace. There does not appear to be a correlation between the presence of the vapor barrier in the crawlspace and the presence or level of mold on the windows in the house.

There appears to be a correlation between the number of people and whether there is mold present on the window sills; however, the number of people does not affect the quantity of mold on the windows. There appears to be a trend that the more people there are in a house, the more likely it is to have mold, and the heavier the mold covering is likely to be.

There was not a significant relationship between the number of occupants, the foundation type, the number of bathrooms, the presence of a vapor barrier in the crawlspace, whether or not a home met BEES ventilation, or the ACH rate of the home at -50 Pascals and the presence and/or level of mold on the walls and/or windows.

Proper and adequate ventilation is the key to preventing mold problems in homes.

Sooting Summary

Sooting is not an indoor air quality problem by itself, but it may indicate other problems are going on in the home. Usually Sooting occurs when an appliance is backdrafting but it could also be related to smoking, heavy candle use or a wood burning appliance.

Sooting is sometimes called ghosting, and it is a secondary sign that we use to evaluate what may be going on in a home. Sooting happens when conductive heat loss occurs at wood joints in the home. This type of heat loss is more efficient than through insulated cavities and leaves the wood members and sheetrock inside the home slightly cooler than the rest of the wall. Where this part of the wall is slightly cooler than the rest of the wall, the dew point, or the temperature at which moisture in the air turns to liquid is lower. Microscopic moisture, sometimes unseen to the naked eye, form at these cold spots on the wall. These tiny bits of moisture on the wall then become like magnets to ultrafine particles like dust and soot. Usually these particles come from backdrafting appliances in another part of the house, burning lots of candles, cigarette smoke, or wood smoke. These tiny particles attach themselves to the moisture on the wall making gray or black streaks on the wall. Sooting can be an indication of backdrafting appliances, excessive relative humidity and sometimes inadequate insulation levels.

Sooting was categorized as present or not present in the home. Sooting was also classified as light, medium and heavy. Sooting was considered light if markings only appeared in corners and/or at the wall ceiling intersection where rafters met the top plate. Nails or screws were not visible. Sooting was considered medium if markings appeared in corners and at wall ceiling intersections, and nails or screws were visible as dark gray spots on the wall. Sooting was considered heavy if markings ran the full length of studs from top to bottom plates of walls, or top plate to peak of rafters and nails or screws were visible as dark gray spots.

31 homes of the 100 homes tested had sooting present in the living space.
23 homes of the 100 homes tested had sooting present in the garage.

28% of homes with natural gas had sooting present in the garage and 0% of homes with oil had sooting present in the garage. This suggests that natural gas appliances may backdraft more easily than oil fired because of lower stack temperatures and the fact that most oil fired appliances are induced or forced draft and many natural gas appliances, especially water heaters, are natural draft.

None of the homes with space heating as the heating system type had sooting in the garage. This may be attributed to the fact that homes using a space heating system put the system in the house itself and not the garage.

31.8% of homes with a Category 1 appliance had sooting present in the garage, nearly twice percentage of homes with Category 2 or 3 appliances.

Homes with heating systems located in the garage had nearly five times the percentage of sooting as homes that did not.

Homes with open fireplaces (15.0%) and wood stoves (60%) had sooting present in the garage while homes with air tight wood stoves and sealed gas fireplaces did not. This may be because the open draft of the fireplace and wood stove created negative pressure in the garage which in turn caused back drafting and sooting in the garage.

The more often the fireplace was used the less often sooting was present in the garage. Only homes that used natural gas as the hot water heating fuel type had sooting present in the garage.

Only homes with Category 1 hot water heating appliances had sooting present in the garage.

The percentage of homes with a hot water heating appliance in the garage were more than 6 times as likely to have sooting present the garage than homes with hot water heating appliances in other locations.

The average CO level is nearly 210% higher in homes with sooting present in the living space than in homes without sooting present in the living space.

Homes that met the BEES ventilation standard had more than twice the percentage of garages with sooting present than those that did not meet the BEES ventilation standard.

Of houses with garages, the houses that met BEES through natural air leakage only or natural air leakage and mechanical ventilation were twice as likely to have sooting present in the garage. Houses that met BEES through mechanical ventilation only were three times as likely to have sooting in the garage. Homes that met BEES ventilation requirements through mechanical ventilation were subject to greater pressure imbalances than homes that met BEES ventilation through natural air leakage or did not meet BEES at all. High pressure imbalances contributed to the sooting.

Houses with a combustion appliance that back drafted under worst case scenario were more than twice as likely to have sooting present in the garage.

There was not a significant relationship between type of heating fuel, type of heating system, the heating system combustion category, heating system location, fireplace type, fireplace usage, hot water heating fuel type, hot water heating appliance combustion category, hot water heating appliance location, or whether or not smokers were present and whether or not sooting was present and the level of sooting in the house and the garage.

In conclusion, attention must be paid to adequate combustion air for combustion appliances, especially those located in the garage. Sealed combustion appliances are a much better choice in energy efficient homes than open combustion appliances. Ventilation systems must be properly designed so as not to create excessive pressure imbalances within the home. Ideally, combustion appliances should be located in well detailed mechanical rooms with outside entrances equipped with proper combustion air to limit communication with the garage and living space of the home.

Pressure Imbalance Summary

Pressure imbalance testing was performed on each house. Hoses were run to applicable parts of the house, i.e outside, garage, crawlspace and mechanical room. Hoses were connected to magnehelic gauges and readings were recorded with ± 0.1 Pascal accuracy.

An initial reading was taken with all exhausting equipment in the house turned off to establish a baseline negative pressure. Exhausting fans were then turned on one at a time and the increase or decrease in pressure was noted for each area of the home being measured. This procedure was followed until all exhausting fans and/or ventilating equipment in the house was on. It is generally recognized that heating appliances located within the home are subject to certain pressure limitations. If the pressure limitation of the appliance is exceeded or the appliance itself is in need or repair, a backdraft condition may occur, where pollutants generated during the combustion process are pulled in to the house.

Back draft testing was performed on all homes. All exhausting and ventilating fans in the house were turned on and the house was placed under worst case scenario pressure imbalance conditions. The weakest combustion category appliance was turned on with all fans and ventilating equipment in the house on. Readings with the ultrafine particle counter were taken in the vicinity of the appliance and recorded. A jump in particle count of at least twice the number previously noted during the initial ultrafine particle sweep or an increase of 2,000 ppc/m was considered back drafting.

The average maximum depressurization of all homes in relation to any other part of the home was -9.0 Pascals.

The average maximum depressurization of the largest 3 fans in all homes in relation to any other part of the home was -8.2 Pascals.

The average total depressurization between the home and the outside was -8.3 Pascals.

The average total depressurization between the home and a garage was -5.2 Pascals.

The average total depressurization between the home and a crawlspace was -3.2 Pascals.

The average total depressurization between the home and a mechanical room was -2.6 Pascals.

There was not a significant statistical relationship between the maximum home depressurization and radon average. However, the number do show a strong trend of increasing radon levels parallel to increasing house depressurization levels.

Homes where the maximum negative pressure imbalance exceeded the combustion category rating of the weakest appliance were 65% more likely to back draft that those where the weakest combustion appliance was within negative pressure limitations.

Homes with natural gas fired heating appliances were 256% more likely to back draft under worst case negative pressure imbalance testing than homes with oil fired heating appliances.

43.2% of homes with natural gas fired hot water appliances had a combustion appliance back draft under worst case negative pressure imbalance testing. 14.3% of homes with oil fired hot water appliances had a combustion appliance back draft under worst case negative pressure imbalance testing. 18.4% of homes with electric hot water appliances had a combustion appliance back draft under worst case negative pressure imbalance testing. Electric hot water appliances do not produce CO. Only a single home used propane as a hot water heating fuel, and no combustion appliances back drafted under worst case negative pressure imbalance testing.

Homes without combustion air present for the weakest combustion category appliance were 32% more likely to experience back drafting than homes with combustion air present for the weakest combustion category appliance.

Over half of the homes with a Category 1 hot water heating appliance experienced back drafting.

Statistical analysis was run on maximum house depressurization vs. contaminant levels. No significant correlation was found for; radon, living space carbon monoxide, garage carbon monoxide, carbon dioxide, ultrafine particles, or living space humidity levels.

Statistical analysis was also run on house with relation to crawlspace, garage and mechanical room vs. contaminant levels. No significant correlation was found for; radon, living space carbon monoxide, garage carbon monoxide, carbon dioxide, ultrafine particles, or living space humidity levels.

Statistical analysis was run on whether or not the combustion appliance in the home was within its combustion category depressurization limits vs. the average contaminant means. No significant correlation was found for; radon, living space carbon monoxide, garage carbon monoxide, carbon dioxide, ultrafine particles, or living space humidity levels.

Statistical Analysis was run on whether or not an appliance back drafted under worst case negative pressure imbalance testing and the maximum negative pressure in the house, the maximum negative pressure generated by the three largest fans. No significant findings were established.

In conclusion, negative pressure imbalances in the home must be strictly controlled to maintain a healthy environment. Attention must be paid to adequate combustion air for combustion appliances, especially Category 1 natural gas water heaters. Sealed combustion appliances are a much better choice in energy efficient homes than open combustion appliances. Ideally, combustion appliances should be located in well detailed mechanical rooms with outside entrances to limit communication with the garage and living space of the home.

Ventilation Summary

Ventilation is a combination of air movement within a building and the introduction of fresh outdoor air. When ventilation in a building is at proper levels, the indoor air will be fresh and free from pollutants and excess moisture. Not enough ventilation in a building will result in poor indoor air quality. This means pollutants will be allowed to accumulate in the air and excess moisture allowed to build up, creating an unhealthy environment. Ventilation, when combined with control of air polluting sources within the home, greatly improves the quality of indoor air.

The standard for ventilation of residential homes in Alaska is found in Alaska's Building Energy Efficiency Standard, heareafter referred to a BEES. The BEES Standard was originally authored September 1, 1991 and took effect January 1, 1992. It provides a minimum standard for thermal resistance, air leakage, moisture protection, and ventilation in energy efficient buildings. It was put in effect to provide a minimum ventilation and thermal energy requirements for new construction. Alaska's BEES is designed to provide adequate levels of ventilation that deal with moisture and pollutants generated within the home.

There are two options that can be followed when adhering to BEES ventilation requirements. Simply enough, these two ventilation options are called Option I and Option II. Option I is based on the ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) 62 –99 standard. Option II is a standard adopted by the state of Alaska. Both options are acceptable methods of meeting minimum ventilation requirements.

Option II is much simpler to use than Option I, as it applies only to residential buildings and normally encountered household pollutants. Option II also assumes that outdoor air is suitable for ventilation. Option II requires two different procedures for determining minimum ventilation rates, **Table 2.3** or the **0.3 Air Changes per Hour (ACH)** method. The greater of these two methods is used to determine the minimum ventilation requirement under BEES Option II.

0.3 Air Changes per Hour (ACH) method.
Find the total volume of the conditioned space in the home. Divide the total cubic feet by 60, the number of minutes in an hour. This give the number of cubic feet of air exchanged each minute to provide one air change in one hour. Finally, take the cfm exchanged each minute and multiply that by 0.3, giving the minimum ventilation requirement.

Table 2.3
In order to determine minimum ventilation requirements, we must follow certain steps:
Add the base flow cubic feet per minute (cfm) rate for each room in the building. Add the continuous exhaust flow rate for each room in the building. The total ventilation air shall be the larger of the total base flow cfm or the total continuous exhaust flow cfm. This is the minimum supply and exhaust air that shall be provided. If the total continuous exhaust cfm is larger than the total base flow cfm, then supply air shall be increased to match exhaust cfm flow rate, or part of the exhaust rate may be accomplished by intermittent exhaust, meaning exhaust not controlled by a timer or other device. The ventilation requirement for a combined room such as living/dining or kitchen/dining may be counted as if each were an individual room. Ventilation into a category B room called for in the base flow rate column can be provided indirectly from a category A room through continuous exhaust from a category B room. The ventilation system design shall account for any air flow loss as a result of design specifics or installation effects. A minimum air flow rate as specified shall be verifiable after installation is complete.

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Table 2.3 Minimum Ventilation Air Requirements, CFM			
Space	Base Flow Rate	Exhaust	
		Continuous	Intermittent
Category A Rooms			
Master Bedroom	20		
Other Bedrooms	10		
Living Room	10		
Dining Room	10		
Family Room	10		
Recreation/Hobby Room*	10		
Non-Partitioned Basement	20		
Other Habitable Rooms	10		
Category B Rooms			
Kitchen	10	25	100
Bathroom	10	20	50
Laundry Room*	10		
Utility/Work Room (not mechanical room)	10		
*These rooms may generate excessive indoor air pollutants and may require additional exhaust capability.			

Of homes that **did meet the BEES** standard under either Option I or Option II:

- 63.6% used natural air leakage
- 6.1% used an exhaust only system
- 6.1% used an exhaust only with pressure relief vents system
- 24.2% used an HRV

Of homes that **did not meet the BEES** standard under either Option I or Option II:

- 85.1% had no ventilation system
- 4.5% had an exhaust only system
- 0% had an exhaust only w/ pressure relief vents
- 10.4% had an HRV.

Although not statistically significant, **t**he average radon level was 35% less in a home that met BEES ventilation than a home that did not. The average living carbon monoxide level was 29% less in a home that met BEES ventilation than a home that did not. The average carbon dioxide level was 12% less in a home that met BEES ventilation than a home that did not. The average living space relative humidity level was 6% less in a home that meet BEES ventilation than a home that did not.

Homes with a mechanical ventilation system were more likely to meet BEES than homes without a mechanical ventilation system.

Homes that met the BEES ventilation standard had more than twice the percentage of garages with sooting present than those that did not meet the BEES ventilation standard. Sooting is not an indoor air quality problem by itself, but it may indicate other problems are going on in the home. Usually Sooting occurs when an appliance is backdrafting but it could also be related to smoking, heavy candle use or a wood burning appliance. Sooting is sometimes called ghosting, and it is a secondary sign that we use to evaluate what may be going on in a home. It is important to note that homes that met the BEES ventilation standard are tighter than homes that did not meet the BEES ventilation standard. Also, adequate combustion air was not typical of these homes.

Houses with garages that met BEES through natural air leakage only or natural air leakage and mechanical ventilation combined were twice as likely to have sooting present in the garage as homes that did not meet BEES. Houses that met BEES through mechanical ventilation only were three times as likely to have sooting in the garage as homes that did not meet BEES. Homes that met BEES were tighter than homes that did not, and combustion air was not typically present.

Homes with no ventilation system were 333% more likely to have mold present on the window sill than not. Homes with HRVs were 50% less likely to have mold on the window sills as not.

Homes with an unbalanced HRV had mold present on the windows 50% more often than homes that had a balanced HRV.

It appears that there is a trend that a balanced HRV unit will decrease the likelihood of mold and the severity of mold on the windows.

Statistical analysis was run on whether or not ventilation met BEES vs. contaminant levels. No significant correlation was found for; radon, living space carbon monoxide, garage carbon monoxide, carbon dioxide, ultrafine particles, or living space humidity levels.

Statistical analysis was run on the type of ventilation (natural air leakage, exhaust only, exhaust only w/ pressure relief vents and HRV) vs. contaminant levels. No significant correlation was found for; radon, living space carbon monoxide, garage carbon monoxide, carbon dioxide, ultrafine particles, or living space humidity levels.

Statistical analysis was run on the method of ventilation (Option I, Option II, both or neither) vs. contaminant levels. No significant correlation was found for; radon, living space carbon monoxide, garage carbon monoxide, carbon dioxide, ultrafine particles, or living space humidity levels.

Statistical analysis was run on the type of ventilation (natural air leakage, exhaust only, exhaust only w/ pressure relief vents and HRV) vs. whether or not condensation was present on the windows, the level of condensation on windows, whether or not condensation was present in the bathroom and the quantity of condensation in the bathroom. No significant correlation was found.

Statistical analysis was run on method of ventilation (Option I, Option II, both or neither) vs. whether or not condensation was present on the windows, the level of condensation on windows, whether or not condensation was present in the bathroom and the quantity of condensation in the bathroom. No significant correlation was found.

Statistical analysis was run on whether or not ventilation met BEES vs. whether or not condensation was present on the windows, the level of condensation on windows, whether or not condensation was present in the bathroom and the quantity of condensation in the bathroom. No significant correlation was found.

Proper ventilation and adherence to the BEES ventilation standard is the solution to reducing indoor air quality contaminants. Mechanical ventilation is much more effective than natural air leakage, and is strongly recommended with strict attention being paid to pressure imbalances.

Garage Summary

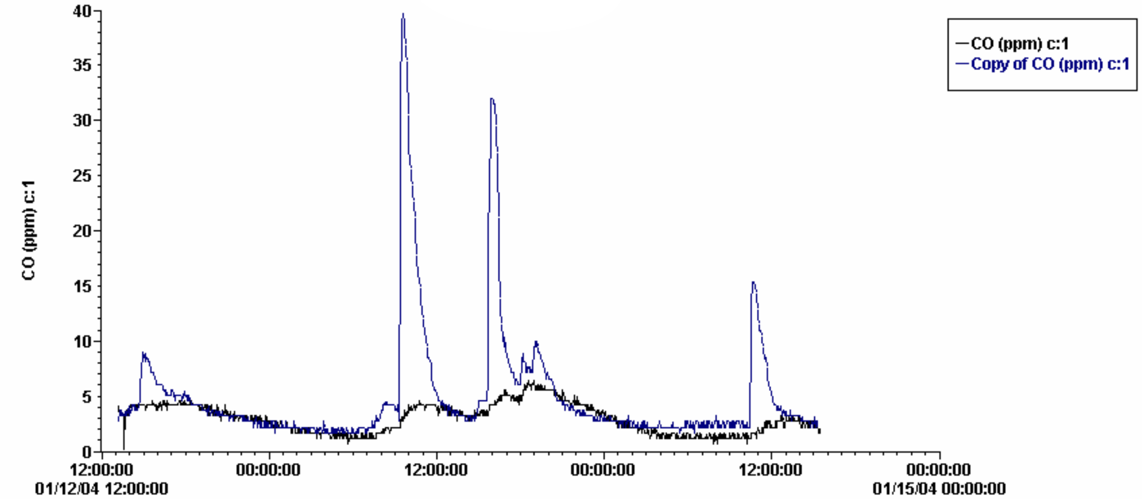
Garages usually contain cars that are large sources of Carbon Monoxide whenever the engine is running, even if only for brief periods while the car is coming and going. If the garage is only used for storage, there can still be problems if fuel, paint, or cleaning agents are present, as these and many other items contain volatile organic chemicals.

Houses with attached garages deserve special attention because they can be very susceptible to garage to house communication of pollutants.

In the 100 homes of the study 75% had a garage attached to the home in some fashion. Of these homes 69 were attached by one or more walls in the house and the remaining 6 were tuck-under garages.

In homes with an attached garage, they are more likely to have the heating and hot water appliance in the garage than any other place in the house. This makes the garage an important area to keep as sealed as possible form the house because not only is there a source of pollution from cars going in and out of the garage, the heating and hot water system can also be a source of pollution.

As we have determined there is a difference in homes that do not have a garage and homes that do have a garage in terms of contaminant levels. But these average only give some of the picture, it is important to see the connection between the garage and the house. We can do this by looking at home’s data logging graphs, and follow the spike of CO that happened when the car pulled into the garage as it moves into the house.



While the following spike of CO in the house is by no means as high as the spike in the garage, it is important to recognize that there is a slight increase in the level of CO in the house due to a contaminant produced within the garage.

As the frequency of car use in the garage increases, so does the average level of CO2 in the living space.

There was not a significant relationship between the level of CO, CO2, or how the garage was attached to the house and frequency of garage use.

The communication between houses and garages is very real. The average total depressurization between the home and a garage was -5.2 Pascals. Proper sealing between the house and garage, as well as reducing negative pressure imbalances between the house and garage are important to preventing garage contaminants from entering the home.

Heating System Summary

Heating systems are an integral part of every home; they may also be a pollutant source within the home. The combustion process which most home heating systems rely upon produces many harmful by-products which are unhealthy. Heating systems work best when properly installed and maintained, and are sensitive to negative pressure imbalances. Alaska's own Building Energy Efficiency Standard sets guidelines for appliance types and negative pressures in the home.

For a building using a Category I fuel-burning appliance, the reference exhaust air flow shall not decrease the pressure in the building relative to the outside by more than 5 Pascals of pressure.

For a building using a Category II appliance, the reference exhaust air flow shall not decrease the pressure in the building relative to the outside by more than either 10 Pascals

(Pa) of pressure or the value for which the appliance has been certified by an accredited certification agency.

For a building using a Category III appliance, the reference exhaust air flow shall not decrease the pressure in the building relative to the outside by more than either 20 Pascals of pressure or the value for which the appliance has been certified by an accredited certification agency.

If no fuel-burning appliance is installed in a building, the reference exhaust air flow shall not contribute to decreasing the pressure in the building relative to the outside by more than 20 Pascals of pressure. (BEES, 2001)

The percentage of homes with a hot water heating appliance in the garage were more than 6 times as likely to have sooting present the garage than homes with hot water heating appliances in other locations.

Only homes with Category 1 hot water heating appliances had sooting present in the garage.

Only homes that used natural gas as the hot water heating fuel type had sooting present in the garage.

Homes with heating systems located in the garage had nearly five times the percentage of sooting as homes that did not.

31.8% of homes with a Category 1 appliance had sooting present in the garage, nearly twice percentage of homes with Category 2 or 3 appliances. This may be attributed to the fact that Category 1 appliances backdraft at lower negative pressures than Category 2 or 3 appliances.

28% of homes with natural gas had sooting present in the garage and 0% of homes with oil had sooting present in the garage. This suggests that natural gas appliances may backdraft more easily than oil fired because of lower stack temperatures and the fact that most oil fired appliances are induced or forced draft and many natural gas appliances, especially water heaters, are natural draft.

Of the homes with appliances that back drafted under worst case scenario pressure imbalance testing, 42.1% were within combustion category depressurization limits and 57.9% were not. Homes where the maximum negative pressure imbalance exceeded the combustion category rating of the weakest appliance were 65% more likely to back draft that those where the weakest combustion appliance was within negative pressure limitations.

Homes with natural gas fired heating appliances were 256% more likely to back draft under worst case negative pressure imbalance testing than homes with oil fired heating appliances.

43.2% of homes with natural gas fired hot water appliances had a combustion appliance back draft under worst case negative pressure imbalance testing. 14.3% of homes with oil fired hot water appliances had a combustion appliance back draft under worst case negative pressure imbalance testing. 18.4% of homes with electric hot water appliances had a combustion appliance back draft under worst case negative pressure imbalance testing. Only a single home used propane as a hot water heating fuel, and no combustion appliances back drafted under worst case negative pressure imbalance testing.

Homes without combustion air present for the weakest combustion category appliance were 32% more likely to experience back drafting.

Over half of the homes with a Category 1 hot water heating appliance experienced back drafting.

Statistical analysis was run on whether or not the combustion appliance in the home was within its combustion category depressurization limits vs. the average contaminant means. No significant correlation was found for; radon, living space carbon monoxide, garage carbon monoxide, carbon dioxide, ultrafine particles, or living space humidity levels.

Statistical Analysis was run on whether or not an appliance back drafted under worst case negative pressure imbalance testing and the maximum negative pressure in the house, the maximum negative pressure generated by the three largest fans. No significant findings were established.

In conclusion, negative pressure imbalances in the home must be strictly controlled to maintain a healthy environment. Attention must be paid to adequate combustion air for combustion appliances, especially Category 1 natural gas water heaters. Sealed combustion appliances are a much better choice in energy efficient homes than open combustion appliances. Ideally, combustion appliances should be located in well detailed mechanical rooms with outside entrances to limit communication with the garage and living space of the home.

Energy Rating Summary

An energy rating was performed on all 100 homes. Data from each home was collected on site, i.e. square footage, volume, foundation type, wall type, heating system, insulation, air leakage etc. All of this information was entered into a computer program called AkWarm which would then rate the homes on a scale of 1-100 points. A homes point rating has an equivalent star rating which is used to categorize a home’s energy efficiency.

Points	Rating	Points	Rating
0-39	1★	73-77	3★ +
40-49	1★ +	78-82	4★
50-59	2★	83-87	4★ +
60-67	2★ +	88-91	5★
68-72	3★	92-100	5★ +

(AHFC Website, 2004)

A four star plus or greater home meets the current BEES energy efficiency standard. These ratings were used to determine whether or not the star rating or energy efficiency of the home had any effect on the indoor air quality.

Of the 100 homes in the study, the energy ratings for the buildings ranged from a two star rating all the way through a five star rating. The majority of these buildings had a star rating of four to four star plus with 27% and 21% respectively. There was an even split of homes that were below the 4 Star standard (42% of the homes), and the homes at or above the 4 Star Standard (58% of the homes).

Homes with a rating of four stars or less were more likely to have mold present on the windows and walls than homes that rated at 4 star plus or above. 4 star plus and above homes use more energy efficient building materials which are less likely to generate condensation inside the home. Less condensation inside the home means less mold growth and sooting.

There is no correlation between energy efficiency in homes and poor indoor air quality. The numbers indicate that energy efficient homes are less likely to have problems because they have efficient appliances that have fewer emissions, and in most cases the 4 Star Plus or greater homes have some sort of mechanical ventilation system. 41% of the homes that were 4 Star Plus or greater had an HRV system.

There is no statistically significant relationship between a home’s energy rating and whether or not a combustion appliance back drafted during worst case scenario pressure imbalance testing.

Health Concerns Summary

Reported health concerns came from the initial survey that was used to select the 100 homes for testing. Occupants were also asked in the in-home survey if they thought that they were experiencing any health problems because of the indoor air quality in their home. Reported health concerns were put into two groups; those occupants of homes that thought they were experiencing problems and those that did not. This was further split up into adult reported health concerns and children reported health concerns, if applicable. In all cases the adults answered for the children as to whether or not the children were experiencing any health concerns.

A measurable Indoor Air Quality, hereafter referred to as IAQ, problem was defined as having either radon average level above 4 pCi/L, carbon dioxide average level above 1000 ppm or relative humidity in the living space average above 46.0%.

A perceived IAQ problem was those homes having visible sooting, mold or condensation present in the living area.

An IAQ combination problem was those homes that had both an IAQ problem and perceived IAQ problem as defined above.

Homes where adults reported health concerns had radon levels 72% higher than homes where adults did not report health concerns.

Homes where adults reported health concerns had carbon monoxide levels 44% higher than homes where adults did not report health concerns.

Homes where children reported health concerns had radon levels 16.5% higher than homes where children did not report health concerns.

Homes with two measurable IAQ problems were 45% more likely to report health concerns than homes with one measurable health concern.

The more measurable and perceived IAQ problems a home had the more often adults reported health concerns. Half of all homes with one perceived or measurable IAQ problems reported health concerns; 100% of homes with 5 perceived or measurable IAQ problems reported health concerns.

As the number of perceived IAQ problems increased so does the average level of CO in the living space. The average level of CO in the living space in homes with three perceived IAQ problems was 151% than homes with one perceived IAQ problem.

The occupants of the home are a good indicator of whether or not there are indoor air quality problems present. There is a direct correlation between the quality of indoor air and occupant health.

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