Attached Garages and Indoor Air Quality

We spend 90% of our time indoors, so we have to consider how a home's design and construction can affect indoor air quality. To achieve superior indoor air quality it is important to:

- *remove any contaminants at the source of production;*
- *reduce the contaminants built into the house;*
- *exchange the indoor air with fresh outdoor air.*

Perhaps because of our harsh northern climate, or because we have become such slaves to creature comfort, most new homes have attached garages. However, garages are a source of deadly pollutants: car-starts produce carbon monoxide (CO); stored fuels release benzene; and other materials leak volatile organic compounds.

To prevent problems, the wall between the garage and the house must be built airtight. The Building Code requires that the construction between a garage and a dwelling provide an effective barrier to gas and exhaust fumes. It is "intended to provide reasonable protection from carbon monoxide and gasoline fumes entering the dwelling unit."

Two coroner's reports on deaths caused by CO leakage from attached garages suggested that the building code's notion that the separation between the house and the garage acts as a gas-tight barrier is largely a myth. In practice, it is hard to form an airtight seal in the elements between the house and the garage. We now have evidence that leaks through the wall and ceiling between the garage and the house allow garage air pollutants to enter the house. Studies are finding that from 5% to 85% of the outdoor air leaking into a house comes through the garage and carries carbon monoxide and other contaminants into the house. Houses with attached garages typically have gasoline concentrations that are 10 times higher than outdoor levels, sometimes as much as 50 times higher.

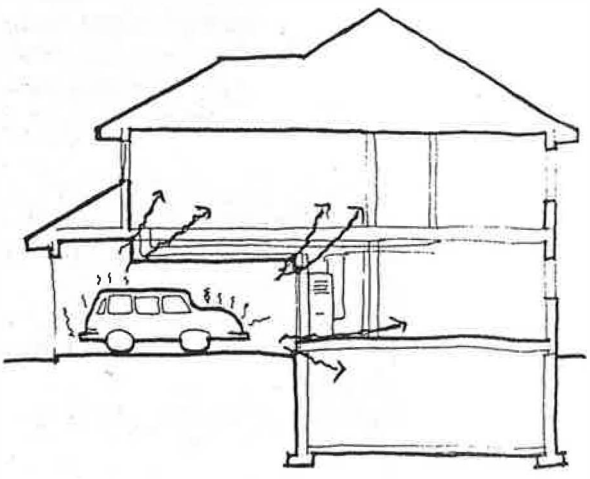
The largest, single indoor air quality concern with an attached garage is that the garage is a source of CO entering the house. Even the Committee that drafts the National Building Code has recognized that the notion of the separation between the house and the garage acting as a gas-tight barrier is largely a myth, but has not been able to find a way to solve the problem. The CMHC and the American Lung Association suggest that, for optimum indoor air quality conditions, garages should be built detached from rather than attached to the house.

Up to 85% of outdoor air leaking into a house can enter through the garage, bringing with it garage air pollutants.

In the past, builders rarely worried about the airtightness of the houses they built. Standard construction practices would produce a house that generated few if any complaints related to airtightness, such as moisture on windows or stale odors. By building houses with a significant amount of air leakage, builders were actually incorporating a passive ventilation system into every house they built. The low efficiency, natural-draft combustion appliances acted like exhaust fans drawing large quantities of outside air into the house. This passive ventilation system was crude, uncontrollable, and created comfort complaints, but it did satisfy the ventilation needs of most houses built more than two decades ago.

However, dilution with outside air in a "loose" house is an inefficient method of removing pollutants. For toxins such as CO, providing more outside air as long as it is still being produced, is dangerous. Even with high volumes of dilution air, the air quality is degraded when pollutants are dumped into a space. High volumes of dilution air also greatly increase heating and cooling costs.

Several studies in the U.S. and Canada have been looking at the amount of garage pollution that enters the house, and what the pollution driving mechanisms are.



When it starts, an automobile generates CO, and should not be allowed to idle inside the garage, even when the garage door is open. Starting a cold car in a garage can send CO levels soaring to more than 80,000 parts per million (ppm) in seconds. In addition, the automobile will offgas a

whole range of fumes, especially as it cools down after use. As the CO leaks into the house it is diluted, so CO concentrations in the house will be lower than in the garage, but can still be at unsafe levels. It can take several hours for CO concentrations in the home to reach safe levels.

Twelve Anchorage area houses with attached garages were studied to assess carbon monoxide movement from the garage into the house. Data was recorded for normal living patterns. One and two-storey homes, with one-, two-, and three-car attached, heated garages were examined. The common surfaces included wall and ceiling areas ranging from 164 to 772 square feet. Results were used to calculate residents' exposure to CO.

It was found that CO from car-starts in the garage entered all but one of the houses. In four of the twelve houses, the exposure was 60% or more of the EPA exposure limit for ambient air, and in one case carbon monoxide exceeded the EPA limit. Exposure at the EPA limit can result in a carboxyhemoglobin level in the bloodstream at which the at-risk population (e.g., angina patients) begin to exhibit adverse symptoms.

In all but one of the houses, the house was at a lower pressure than the garage, thus sucking in garage pollutants.

Carbon Monoxide

Carbon monoxide is a colorless, odorless, tasteless, non-irritating, and highly toxic gas produced when carbon-based fuels burn incompletely. Complete combustion of carbon and oxygen produces carbon dioxide ($C0_2$), a non-toxic gas. Incomplete combustion happens when there is insufficient combustion air, insufficient time for complete combustion, incomplete mixing of air and fuel, or when the temperature drops below the combustion temperature. As CO is lighter than air, it moves easily throughout the house.

Carbon monoxide is absorbed rapidly by the lungs and quickly passes into the blood. Carbon monoxide replaces oxygen in the bloodstream, causing CO intoxication and a lack of reasoning.

Carbon monoxide poisoning can be prevented by:

- ✔ *The proper design, installation, and maintenance of gas appliances.*
- ✔ *Venting combustion products to outdoors.*
- ✔ *Installing warning devices (carbon monoxide detectors).*
- ✔ *Preventing entry of garage gases into the house*

The affinity of CO and red blood cells (hemoglobin), is 200 to 270 times greater than the affinity of oxygen and hemoglobin. Hemoglobin carrying CO (carboxyhemoglobin) is not able to release oxygen to the tissues. Even small amounts of carbon monoxide in the air breathed will quickly increase the percentage of carboxyhemoglobin. Mild CO poisoning feels like the flu, but more serious poisoning can lead to breathing difficulty and death. Just how sick people get from CO exposure varies greatly from person to person, depending on age, health, concentration and length of the exposure. High concentrations are dangerous even for a short time.

Carbon monoxide is the leading cause of poisoning deaths in the U.S., where 3,500 to 4,000 people die annually, and an estimated 10,000 people lose a day's work or seek medical attention. Fires are the main cause of the fatalities, but automobile exhaust in attached garages and faulty heating equipment cause about one-third of the deaths. Canadian numbers would be similar, in proportion to our population.

However, the true incidence of CO exposure is unknown and may be greatly underestimated because CO exposure can be easily misdiagnosed. In a 1995 incident in Ohio, five persons went to the local hospital with flu-like symptoms. Relatives asked the doctor three times if the cause could be carbon monoxide poisoning, but he said no, it was the flu. The family was sent home and three days later all five died of carbon monoxide poisoning. A Kentucky study found that 23.6% of persons showing up at a hospital during February 1985 had elevated carboxyhemoglobin concentrations. None were initially diagnosed as suffering from carbon monoxide poisoning.

Attached garages increase CO problems in the home because houses are kept closed during winter, reducing air change to the outside, and keeping more CO inside for longer periods. In cold weather, vehicles also tend to be warmed in the garage for longer periods.

Cold engines produce higher concentrations of carbon monoxide for longer periods. In a cold start, the engine is cold but the fuel mixture is rich (causing more CO). The catalytic converter is also cold and ineffective. Even well-tuned engines will produce more than 80,000 ppm for the first minute or two of operation. The CO concentration will

drop to 1,000 ppm or less after 5 to 15 minutes running time.

The rate of emission from a typical gasoline engine can be so high (30,000 to 100,000 ppm) that it is difficult to provide adequate ventilation. In one test, a 5.5 horsepower, gasoline-powered pressure washer was run in a double garage with both doors and windows open, and an open vent. Within 12 minutes, CO concentrations in the garage rose to 658 ppm.

Air Tight Construction Practices

How can one protect against carbon monoxide and other pollutants from the garage entering the house? There is no safe way other than building a detached garage.

Second best is to seal the walls and doors to the house tightly, or to use an exhaust fan in the garage. A garage exhaust fan can prevent CO from entering the house. A properly-sized fan venting to outdoors will lower the pressure in the garage, prevent CO from entering the house, and speed the removal of CO. However, the fan could depressurize the house. Vented appliances (furnaces, water heaters, and boilers) must be checked for proper operation after a garage fan is installed. Even with a garage fan, running an engine in the garage is unsafe.

Since carbon monoxide does not attach itself to surfaces in the garage, a complete air change will remove all the CO. With doors on opposite sides of the garage open, this will probably take 5 minutes or less. With doors open on only one side, it will take longer and vary depending on wind and air flow.

What is more disturbing is how often heating and ventilating equipment is placed in the garage, or in a space accessible only through the garage. The problem exists whether the heating system is forced warm air with ducts or hot water with piping in the garage. Observations have found especially high levels of CO transfer into the house when forced-air heating systems are located in the garage.

If the house pressure is at a lower pressure than the garage, air from the garage will flow into the house.

The Healthy House Book

While there have been significant strides toward improving some facets of the environment, the air quality inside our houses is almost always more polluted that the air we breathe outdoors. The reasons for this are sometimes simple, sometimes complex. But the good news is that there are solutions.

For more than a decade the standard reference book for information on the health effects of building materials and for locating less-toxic alternatives has been ***The Healthy House*** book. Now in its 4th edition, it contains much more information than the original 1989 edition. Besides being revised, expanded, and updated, it now also contains articles by 50 healthy house professionals from across North America.

The book contains addresses, phone numbers, and web sites for more than 600 organizations and suppliers, and with more than 1,300 references to more in-depth information, no other book on the subject matches its completeness.

Author John Bower has been a house designer, home builder, consultant, writer, and lecturer promoting healthier construction practices since 1984.

The Healthy House: How to buy one, How to build one, How to cure a sick one
by John Bower 448 pages, US $ 23.95
The book can be ordered directly from the Healthy House Institute or through bookstores.
Tel./fax: 812-332-5073 or: www.hhinst.com